Policy Sci (2015) 48:51–83
DOI 10.1007/s11077-015-9211-3

Identifying policy frames through semantic network analysis: an examination of nuclear energy policy across six countries

Junseop Shim · Chisung Park · Mark Wilding

Published online: 30 January 2015

Abstract This study uses semantic network analysis to investigate nuclear energy policy frames in six countries: USA, UK, Germany, France, Japan, and South Korea. It is suggested that semantic network analysis represents a useful tool to investigate policy frames in complex policy environments. The discourse of top-level decision-makers is analyzed to highlight similarities and differences in policy frames and to identify the key policy arguments in the integrated network of all six countries. In total, 14 major policy arguments are identified, which relate to the three major frames of energy security, clean energy, and nuclear safety, along with the meta-issue of economic growth. There are differences in the degree of emphasis on each of the frames in the six countries, and Germany can be seen to have diverged the most following the Fukushima accident, as the emphasis is on clean energy, to the exclusion of the other frames. In contrast, both the USA and Japan have framed the issues primarily in terms of nuclear safety and energy security, while the UK and France have stressed the economic growth frame, and Korea has prioritized nuclear safety.

Keywords Policy frame · Text network analysis · Frame analysis · Nuclear energy policy

Introduction

Post-positivistic approaches are increasingly recognized as having much to offer policy analysis (Fischer and Gottweis 2012). From this perspective, complexity is regarded as one of the bases to explore public policy (Lejano 2006). In particular, due to the political

J. Shim · C. Park (✉)
School of Public Service, Chung Ang University, Heukseok-dong, Dongjak-gu, Seoul, Korea
e-mail: csp7111@gmail.com

M. Wilding
School of Nursing, Midwifery, Social Work & Social Sciences, University of Salford, Manchester, UK

dimensions of the policy process there may be multiple perspectives (and interpretations) of the same policy issue (Dunn 2003; Stone 1988). These interpretations are based on the policy frames through which a policy problem and its context are constructed (Schön and Rein 1994).

Still, the major schools of policy analysis have tended to focus on how policy-makers undertake rational choices from among policy alternatives. These dominant approaches largely focus on decision processes for optimal allocation of public resources and, as such, aim to develop techniques to compare alternative ways of achieving specific policy goals so as to identify the optimal means (Stokey and Zeckhauser 1978; Dunn 2003). Instrumental rationality has therefore been central to the development and adoption of policy alternatives.

Viewed from this perspective, it has been argued that the rational choice approach has done little to enhance the overall understanding of political interaction (Green and Shapiro 1994). In particular, the rational choice approach has difficulties accounting for the ways in which policy actors make sense of situations and issues. This is problematic as the outcomes of the policy process vary significantly depending upon how policy actors with bounded rationality construct and understand the situation they face (Stone 1988). Indeed, it should be emphasized that policy-making is not a process of solving problems according to rational and technical criteria (Dayton 2000; Schön and Rein 1994). Rather, the "reality" constructed and perceived by policy actors plays a critical role in explaining how they behave in the policy process. The "frames" that govern policy actors' understanding of policy problems can be understood as the building blocks which guide these perceptions.

Since Goffman's (1974) seminal work on the concept of frames, many researchers have viewed policy frames as a starting point to analyze complex policy processes (Saarikoski 2006; Fischer 2003; Laws and Rein 2003; Schön and Rein 1994). These researchers have employed a variety of analytical techniques to identify policy frames based on diverse theoretical and methodological foundations. Consequently, frame analysis should not be regarded as a unified methodology, but rather a diverse range of methods to analyze discourse, including content analysis, narrative analysis, and discourse analysis (Scheufele 1999).

Still, the extent to which these methods can be used to accurately identify policy participants' mental structures has been questioned. More specifically, these approaches have been criticized for being too generic and not providing the analytic tools to support their own findings about frames (Lukeš 2007). As such, this study suggests that semantic network analysis has the potential to more accurately identify policy frames and to contribute to bridging the shortcomings of other frame analysis approaches. In this regard, this study analyzes policy actors' frames through semantic network analysis. In particular, energy policy discourses across six major nuclear-generating countries (USA, UK, Germany, France, Japan, and South Korea) with significant nuclear power programs are investigated (see Appendix 1).

Discourse on nuclear power is ongoing and changes over time, especially when actors attempt to interpret and understand accidents (Gamson and Mogdiliani 1989). More specifically, nuclear energy represents an appropriate policy area for investigation through frame analysis for the following reasons. First, debates concerning nuclear power pros and cons are prevalent around the world. Since even a small radioactive leak could have tremendous consequences, the risks associated with nuclear power cannot be overestimated, as evidenced by the Fukushima accident. Still, nuclear power is regarded as an environmentally friendly energy source since it reduces greenhouse gas emissions and thus reduces pollution. It is also more efficient than any other energy sources. As a result of

these important but unsolvable concerns, each country's nuclear agenda and orientation have been governed by political discourse and societal values at the national level.

Second, nuclear power policy should not be considered as a domestic policy bound by national territories, because of potential overspill risks. Yet, countries continue to design and implement policies largely based on domestic political, economic, and social conditions. More specifically, each country has, according to its own context, developed different policy stances and frames toward nuclear energy utilization (Teräväinena et al. 2011). Thus, it is relatively difficult to achieve shared nuclear power policy goals across several countries. In order to understand the national situations and to promote agreement, it is necessary to have information on the similarities and differences in policy orientations. Frame analysis of policy actors in different countries represents a way of providing this information.

More specifically, this study analyzes the nuclear power policy addresses and speeches of top-level decision-makers from six countries. In doing so, we aim to understand the similarities and differences between the countries, and produce useful policy insights in the nuclear power field. Semantic network analysis is applied as a potentially useful technique to reveal the hidden meaning of texts, as well as the shared meanings among different actors, by applying the socio-cognitive network concept (Carley 1990).

There has long been an interest in cross-national comparisons of nuclear energy policies, including the countries sampled in the present study. For example, comparisons have been undertaken of West Germany and the USA (Joppke 1991), France and the USA (Daemen 1993; David and Rothwell 1994; Delmas and Heiman 2000), France, Finland, and the UK (Teräväinena et al. 2011), and the USA and Sweden (Nohrstedt 2005). In addition, a handful of studies have focused on framing and reframing in nuclear energy; for example, Bickerstaff et al. (2008) and Corner et al. (2011) examined citizen framing of nuclear policy in the UK. Despite their unique contributions, however, these studies did not provide a comprehensive comparison among major countries with nuclear policies and programs. More importantly, how each country shaped its own nuclear energy frames following the Fukushima accident and how they differ from before have not been fully addressed. The present study therefore aims to contribute to the comparative literature on nuclear energy policy and on the framing of nuclear energy, while simultaneously highlighting the utility of semantic network analysis to identify policy frames.

The changing landscape in national nuclear policies

Nuclear discourse on energy policies is typically viewed as context dependent (Teräväinena et al. 2011). Each country's energy policy has unique features in terms of policy problems and environment, and the paths of policy evolution reflect historical and political contexts. In addition, although the Fukushima accident enticed some nations such as Germany to phase out nuclear power, economic considerations would still be the deciding force (Bradford 2012). Economic factors including the security of energy supplies and energy prices have played important roles in determining the relative viability of nuclear power. In particular, since the "oil shocks" of the early 1970s, energy security has been prioritized in most countries with few natural resources including France, the UK, Japan, and Korea.

It is important to note that environmental issues are discussed from the perspective of international energy governance. More specifically, mitigating climate change and reducing CO_2 emissions have relatively recently become important issues in international

energy discourse (Corner et al. 2011). In 1992, countries joined an international treaty, the United Nations Framework Convention on Climate Change (UNFCC), and subsequent Kyoto protocol in 1997 to cooperatively mitigate climate change (UNFCC 2014). The aim of reducing greenhouse gas emissions has meant that nuclear countries have supported an increase in renewable energy sources and/or nuclear power (EIA 2013). In particular, nuclear energy was viewed as an option to fight against climate change, to enhance energy security, and to promote sustainable development for most nuclear countries (Sirin 2010). International organizations including the UN and the International Atomic Energy Agency (IAEA) also came to play very important roles in driving international cooperation to strengthen the global nuclear safety framework (IAEA 2014). However, as will be discussed below, the countries that have fostered nuclear energy for electricity generation for decades have faced different domestic and international energy policy environments. While the Fukushima accident had a profound impact on the world's environment, economy, and energy policy (Schneider 2013), national policy frames and solutions have differed widely.

In Germany, nuclear power has been a top political issue in recent decades, with continuing debates about when the nuclear plants should be phased out. The topic received renewed attention at the start of 2007 due to the political impact of the Russia-Belarus energy dispute and again in 2011 after the Fukushima accident. In 1998, the coalition government revealed plans to phase out nuclear power by 2022, but in 2009 a 12-year delay was announced. Since Germany has relied on nuclear power for 23 % of its energy, the phaseout would present huge challenges for the national economy and industrial structure, and the government decided to use nuclear as a "bridging technology" to a greener future (BBC News 2011; Burgermeister 2009). However, the Fukushima accident provided the German government with a political umbrella to accelerate phaseout (Srinivasan and Gopi Rethinaraj 2013), and the benefits of competitive advantage in the renewable energy market have been emphasized (Associated Press 2011).

France has vigorously pursued nuclear development, largely to achieve energy independence despite few natural resources. Experiencing energy crisis with the "oil shock" in the 1970s, French policy-makers chose a strategic route to energy independence through nuclear energy (Palfreman 2009). The goals of energy independence and being a net electricity exporter have been used in efforts to win public support for nuclear programs (Sastry and Siegel 2010). As a result, France now has the most refined and extensive nuclear energy programs, with a high degree of energy security and the lowest energy cost in the European Union (Sastry and Siegel 2010). Recently, economic factors have been of utmost importance when considering energy policy. In particular, job creation has been urgent following the Eurozone economic recessions (BBC News 2013). Under the circumstances, despite the Fukushima accident, it is expected that France will remain committed to nuclear energy without notable policy changes (Srinivasan and Gopi Rethinaraj 2013).

Nuclear has been one of the most important energy sources in the UK. However, the country is a net electricity importer, mainly from France. In 2007, the Labour government changed its policy stance from opposing to approving new nuclear power plants and highlighted the role of nuclear plants in a low-carbon mix (DTI 2007). Thus, nuclear power was viewed as not only a means to enhance energy security but as a clean energy source that would satisfy future energy needs and contribute to mitigating climate change (Pidgeon et al. 2008; Corner et al. 2011). Government policy on nuclear power has remained largely unchanged since then; even the Fukushima accident did not derail plans to replace old reactors with new ones (WEC 2012). Indeed, the UK government sees itself as at the

forefront of the "nuclear renaissance" (UK Government 2013). With the most ambitious de-carbonization targets in the world, including an 80 % reduction in greenhouse gas emissions by 2050 (HM Government 2013), the UK is likely to continue developing nuclear energy while working toward CO_2 reduction.

As another country with limited natural resources, the 1973 oil crisis led Japan to prioritize energy independence and therefore the strategic development of nuclear energy. Prior to the 2011 accident, Japanese nuclear power had been viewed as a success story (Bradford 2012). However, Japanese nuclear policy has since come to face a different domestic and international policy environment (Vivoda 2012; Hayashi and Hughes 2013). The government subsequently accepted as inevitable a fundamental change in its nuclear safety systems (SEOMUN XIV Chair Research Report 2011). There were strong calls from the public for the abandonment of nuclear policies; trade off margins between benefits and risks of nuclear power, socially acceptable before the accident, no longer existed (Srinivasan and Gopi Rethinaraj 2013). Under the circumstances, the Democratic Party of Japan (DPJ) government announced a shift in energy policy through a slow phaseout of nuclear power by 2030. However, due to the fragility of Japan's energy security (IEE Japan 2012), in March 2013, returning Prime Minister Shinzo Abe pledged to conduct a zero-based review of the long-term nuclear phaseout policy. Apparently, given the extremely low-energy self-sufficiency rate of 4 % without nuclear power, Japan has limited policy options for ensuring its future energy security (Vivoda 2012; Wilson Center 2012; Itoh 2013). Simply put, the Japanese government has to find imaginative ways of balancing strong public opposition with energy security through the continued development of nuclear energy.

In Korea, since the long-term economic development plans of the 1960s, nuclear energy has been a strategic priority from the perspective of energy security and energy production efficiency (WNA 2014a, b). In 2010, the Korean government announced the aim of exporting 80 nuclear reactors by 2030, and thus to become the world's third largest supplier of nuclear technology (WNN 2010). In November 2011 after the Fukushima accident, the Korean government reconfirmed its commitment to nuclear energy (Bradford 2012) and the construction of six new reactors by 2016. Indeed, due to its deemed strategic importance, the Korean government decided to pursue nuclear energy development in the face of public opposition. However, this has been accompanied by establishing the Nuclear Safety and Security Commission as a new independent regulatory agency in 2011, with the aim of strengthening safety and regulations, thereby reducing the public's risk perception and ultimately opposition.

The Atomic Energy Act of 1954 was the emblematic beginning of civilian nuclear development in the USA (Daemen 1993), and the nuclear industry underwent tremendous expansion until the mid-1970s. The USA stepped back from the nuclear option around 1974, however, due to (1) revised forecasts of nuclear energy demand, (2) escalation of public opposition, and (3) shifting production costs (Daemen 1993). As a result, about 50 % of nuclear facilities were canceled or delayed indefinitely (Daemen 1993), and no new nuclear power plants have been constructed since 1977. Further, the Three Mile Island disaster of 1979 led the US government to reduce nuclear investment, effectively ending progress in the development of civilian nuclear energy technology (Wilson Center 2012). Since then, the USA has lacked political consensus on energy policy, except for broad agreement on the necessity of strict nuclear regulation (Sastry and Siegel 2010). More recently, US energy policy has shifted increasingly to natural gas. Under the "shale gas revolution," it is predicted that natural gas will be the most used fuel in the USA by 2030 (Wilson Center 2012). However, in late 2013, the Nuclear Regulatory Commission (NRC)

was reviewing nine applications to construct 14 new nuclear power plants. It should also be noted that in June 2013, President Obama announced a plan to fight climate change, which raised the importance of carbon emissions. Under the circumstances, the Fukushima disaster has had little direct impact on the future of the nuclear energy discourse in the USA (WEC 2012), except more stringent safety regulation and delays in licensing new nuclear plants (Srinivasan and Gopi Rethinaraj 2013). Currently, although nuclear might not be at the forefront of future energy policy discourse, the USA would continue its commitment to nuclear energy (WNA 2014a, b).

Frame analysis approaches in policy analysis

In policy analysis, three major schools of thought have evolved over the decades: the traditional school of policy science, the school of politics, and the consensual dispute resolution school (Schön and Rein 1994). Though they are based on different theoretical and epistemological foundations, they share assumptions about instrumental rationality. They assume that policy actors including policy-makers choose the best means to achieve their goals. Nevertheless, these three schools have failed not only to explain the intractability of policy disputes but also to provide possible solutions to the disputes (Schön and Rein 1994).

Recently, as an alternative to the three schools of thought, frame analysis has gained momentum. Schön and Rein (1994) suggested that policy analysis can only be effective through taking conceptual framing into account. Frame analysis emphasizes that each actor's policy position rests on underlying structures of belief, perception, and conceptualization (i.e., frames). Through framing, individuals shape a particular mental construct or restructure their understanding of an issue (Chong and Druckman 2007). More specifically, a policy frame refers to considerations regarding certain features and implications of the policy issue. When developing a policy argument, politicians may deliberately attempt to formulate a policy frame by highlighting certain features of reality and by employing metaphors, stories, and discourses (Dayton 2000; Saarikoski 2006). However, competing policy frames can convey contrasting and often incompatible views of reality, and policy actors with different policy frames may clash.

Frames are most clearly detectable through policy actors' discourse on a policy situation and issue. Based on van Dijk's (1977) definition of discourse, policy discourses can be considered to be comprised of policy addresses, speeches and dialog about policy issues. Yet, language is not a neutral system of communication, because it is always based on frames, conceptual metaphors, and stories (Lakoff 1996). Indeed, Majone (1989: 1) noted that "public policy is made of languages" of which the central role is to deliver argument and emphasized that formal speech aims both to clarify the decision maker's political position and to persuade audiences to accept this position. Therefore, policy frames can be captured by analyzing core arguments in policy texts collected from written or oral forms of policy discourse. As noted above, a number of diverse frame analysis techniques have been utilized since the seminal work of Goffman (1974), including content analysis (Chong and Druckman 2007, 2011), narrative analysis (van Eeten 2007), and most of all, discourse analysis (Schön and Rein 1994; Hajer 1995; Scheufele 1999; Dayton 2000; Saarikoski 2006). However, there is little consensus on how to identify frames.

Although policy frame researchers do not share a unified frame analysis technique, it is possible to categorize policy frame analysis into quantitative and qualitative approaches as presented in Table 1. Drawing on the deductive approach, quantitative frame researchers

Table 1 A comparison of quantitative and qualitative approaches to frame analysis

	Quantitative frame analysis	Qualitative frame analysis
Assumption	Frames are objectively identifiable	Frames are embedded in text and may change depending upon context
Coding scheme	Developed prior to research: deductive Classification of keywords and terms as indicators of a frame	Frames emerge during research: inductive Researcher's interpretive identification
Coding	Objective: reliability and validity Utilization of content analysis software	Subjective: trustworthiness Intercoder reliability
Analysis	Statistical analysis: frequency analysis, correlation analysis, cluster analysis	Discourse analysis: description of frame characteristics

believe that a frame can be crystallized explicitly and objectively through keywords and terms in a discourse. They examine frames that were defined and operationalized prior to the analysis (de Vreese 2005). To this end, they analyze policy discourses through quantitative measures of keywords and terms as indicators of frames (Entman 1993; Cappella and Jamieson 1997; Triandafyllidou and Fotiou 1998; Semetko and Valkenburg 2000), by measuring the tone of keywords and terms (i.e., pro/anti), and classifying arguments according to predefined frames (Baumgartner et al. 2008). In a similar vein, some suggest themes, metaphors, exemplars, catch phrases, depictions, and visual images as framing devices (Gamson and Mogdiliani 1989; Nelson et al. 1997). Despite significant contributions, quantitative frame researchers have been criticized for being over-dependent on specific words and terms while neglecting contexts and underlying meanings of arguments.

In comparison, more studies have been conducted using qualitative frame analysis. In these studies (e.g., Schön and Rein 1994; Hajer 1995; Creed et al. 2002; Lewicki et al. 2003), frames are usually identified implicitly through researchers' subjective interpretation of stories and discourses, using techniques borrowed from discourse analysis and sociolinguistics. Qualitative studies also tend to be inductive as they do not attempt to make predictions through theoretical frameworks with a priori defined policy frames (de Vreese 2005). Instead, frames emerge from the analysis of text data. This approach has been criticized for not providing an objective way to operationalize and measure frames, and due to the difficulties of replicating findings (Hertog and McLeod 2001; de Vreese 2005).

As noted above, neither approach has provided appropriate tools for the concrete identification of policy actors' frames. Despite ongoing methodological debates, most frame researchers agree that policy frames can be crystalized through policy stories and discourses. On this basis, this study attempts to combine quantitative and qualitative methods to analyze policy frames through semantic network analysis.

Semantic network analysis as a method for frame analysis

Since the early 1990s, network analysis of text data has become a widely used method in various academic fields including sociology (Carley 1993), political science (Maynard 1997; Kim et al. 2011), information science (Popping 2003; Diesner and Carley 2004; Doerfel and Connaughton 2009), computer science (Diesner 2012), communications (Rice

and Danowski 1993; Jang and Barnett 1994; Doerfel 1998; Doerfel and Barnett 1999; Kwon et al. 2009; Doerfel and Marsh 2003; van Atteveldt et al. 2008), conflict management (Young 1996), poetics (Carley 1994), and linguistics (Smith 2003; Smith and Humphreys 2006). As a result, many different theories and methods have been developed for text-based network analysis, and there is no single agreed method and designation of the analysis in the literature (Doerfel 1998; Diesner 2012).

Nevertheless, most previous studies using text data for network analysis can be categorized into three groups depending upon the information extracted (Diesner 2012). First, concept networks, often called semantic networks, can be extracted (Sowa 1992; Rice and Danowski 1993; Jang and Barnett 1994; Carley 1997a, b; Doerfel and Barnett 1999; Popping 2000, 2003; Smith 2003; Smith and Humphreys 2006; Doerfel and Marsh 2003; Doerfel and Connaughton 2009; Kwon et al. 2009; Carley et al. 2011). In these networks, nodes (i.e., concepts) represent salient information from a body of text, and concepts (i.e., words) are "abstract representation of the information that people conceive in their minds" (Diesner 2012: 5). Therefore, by analyzing links between concepts, the researcher can extract implicit meaning and interpret structural properties from networks of words. In this way, researchers attempt to extract and distill more fundamental meanings or abstract information embedded in text (Carley 1994, 1997b). Second, multi-mode networks called meta-networks can be extracted, where nodes represent entities of social systems such as people, groups, locations, and resources (Carley 2002; Diesner and Carley 2004; van Atteveldt et al. 2008; Diesner 2012). Finally, texts or documents can themselves be used as nodes and tied to the social agents (Hummon and Doreian 1989; Moody 2004; Diesner 2012). Of these three types, the present study focuses on semantic network analysis, primarily due to its capacity to extract salient information from text, to describe relationships among concepts, to analyze underlying meanings in text, and to understand the structure of concept networks (Danowski 1982, 1993; Carley and Palmquist 1991; Rice and Danowski 1993; Carley 1997a, b; Jang and Barnett 1994; Doerfel 1998; Popping 2000, 2003; Doerfel and Marsh 2003; Diesner and Carley 2004; Doerfel and Connaughton 2009; Diesner 2012).[1]

Drawing on the literature, semantic network analysis in this study is defined as *network analysis using written texts to identify salient words and concepts in order to extract underlying meanings and frames from the structure of concept networks*. While traditional text analysis (i.e., content analysis) relies on measuring frequencies in order to find the most prominent concepts (Krippendorff 2004), semantic network analysis can identify structural properties through recognition of relations between concepts (i.e., co-occurrence) by applying network analysis techniques. Through utilization of semantic network analysis, this study explores diverse structural properties such as bridging between concepts and substructures of the text, the interrelations of terms, and the most frequently mentioned concepts (Jang and Barnett 1994; Carley 1997a, b; Diesner and Carley 2004, 2005; Kwon et al. 2009; Doerfel and Connaughton 2009).

Further, the methodological capacity of social network analysis to reveal hidden patterns behind social phenomena (Wasserman and Faust 1994; Scott 2000) enables semantic network analysis to identify the implicit or embedded meanings and structure in a text. In other words, semantic network analysis can "generate new, logically implied statements that may not be explicitly stated in texts" (Roberts 1997: 6). This is more than just "reading between the lines," however, as it uses an objective and quantitative approach to reveal the hidden patterns (Doerfel and Marsh 2003). Semantic network analysis firstly

[1] Similarly, Salisbury (2001) and Sherblom et al. (2001) analyzed salient words, image, cognitive construct, and meanings using neural network content analysis.

measures the substructures of the text, before integrating them to induce the main meaning in the text.

Like other types of network, concept networks are composed of subgroups or (local) communities which are tightly knit with many relations inside communities and only a few relations between communities (Newman 2010). Through detecting these substructures and identifying bridging concepts which play a meaning circulation role in the entire network, it is possible to understand the main argument of a text (i.e., the policy frame) and compare differences between different texts.

As a raw data source for semantic network analysis, policy texts are composed of chains of arguments, which are in turn composed of sub-claims and supporting evidence (Toulmin et al. 1984). In order to understand the main argument of a policy text, it is necessary to simultaneously understand the sub-claims in the text and the contribution of these to the main claim. Semantic network analysis enables this understanding through identification of concepts with a meaning circulation role, and through using modularity analysis to disassemble texts into the substructures in which local claims are nested (Newman 2006), before integrating the sub-claims.[2]

Sub-claims can be integrated through the identification of bridging concepts between local communities across the whole network. Though the sub-claim of each local community remains unchanged, bridging concepts between two or more sub-claims allow us to make sense of the various sub-claims that otherwise may appear fragmented. Thus, bridging concepts assist the circulation of meaning between local communities.

Terms with a meaning circulation role can be identified through centrality analysis, which uses degree and betweenness centrality to measure a concept's influence in the network (Freeman 1979). Concepts with high degree centrality play a connector role, indicating the extent to which they are connected to other *adjacent* concepts (i.e., the number of times they co-occur with other words). Concepts with high betweenness centrality play a bridge or gatekeeper role between other concepts in the network.

Concepts can be categorized into four different types, depending on the level of degree and betweenness centrality, as presented in Table 2. First, high-ranking concepts in both categories of centrality can be understood as hubs (especially if the degree distribution follows power law), and their role is to circulate meaning across the entire network (Paranyushkin 2011, 2012). The meaning circulation role can be emphasized if the betweenness centralization index (BCI)[3] is high, because this means that there are a small number of central concepts.

Second, concepts with high degree centrality but comparatively low betweenness centrality can be read as local hubs in the community, because they have a relatively high number of adjacent relationships, which means the connecting role is limited to local actors, and concepts in other communities are not reliant on this concept to connect together. Third, concepts with high betweenness centrality but relatively low-degree centrality can be seen as bridges between local communities. In contrast to the local hub, this concept does not have much influence on adjacent concepts, but many other concepts

[2] Statistical analysis techniques such as multidimensional scaling (MDS), cluster analysis, correspondence analysis, discriminant analysis (Jang and Barnett 1994), correlation analysis, and spatial modeling as a more advance version of MDS (Kwon et al. 2009) can also be used for determining relations among concepts and grouping them through statistical analyses.

[3] BCI measures how centralized the betweenness of the set of actors is (i.e., whether communication in the community depends on one member or many). A BCI reaches its maximum value of 1 when all actors in the network are dependent on one actor to communicate with each other and "its minimum value (0) occurs when all actors have exactly the same actor betweenness index" (Wasserman and Faust 1994: 192).

Table 2 Type of concept by degree and betweenness centrality

	Betweenness	
	High	Low
Degree		
High	Hub in the entire network: meaning circulation role	Local hub in community
Low	Bridging concept between local communities	Peripheral concepts

in various communities could connect together only via this concept. Fourth, concepts that are comparatively low in both categories of centrality are regarded as peripheral concepts which do not play a meaning circulation role.

This study also proposes that shared or overlapping meaning among different actors can be detected through socio-cognitive networks, which integrate individual cognitive networks (Carley 1997b). This is significant, as it is only possible to pursue collective solutions when policy actors reach a shared understanding of the same policy issue (Stone 1988). As such, policy theories have grappled with the issue of how policy actors with different and sometimes conflicting value systems can make adjustments to arrive at a mutual understanding. Semantic network analysis could help to find a shared meaning by combining the respective networks (i.e., individual cognitive networks) into one integrated network (i.e., socio-cognitive network). A challenge is that the meaning of a specific concept could differ when used by individuals in contrasting contexts, because "concepts' structural characteristics are not fixed but dependent on the sociocultural environment and the task being performed" (Carley 1997b: 99). However, if texts can be collected from across the population and an integrated network is built using this population text, we could identify the overall interrelationships between the concepts. In this integrated network, all of the relationships between concepts overlap, which represents all the possible connections between concepts. Thus, variety in the meaning of concepts diminishes (differences are offset and there is convergence toward the average meaning), and the social meaning of concepts can emerge from the integrated network.

Since there is no widely agreed upon method for the construction of integrated text networks, this study applies an exploratory approach. More specifically, concepts used in the integrated network analysis are selected using the following criteria: (1) concepts used by more than two countries, and (2) in the case of concepts used in a single country, only concepts which occur more than three times are included.

Research design

Case selection

The national nuclear energy policy frames of USA, UK, Germany, France, Japan, and Korea are all included in this study. Each of these countries has harnessed nuclear energy for electricity generation for decades, though this has been challenged to varying degrees since the Fukushima accident. The "big five" nuclear-generating countries, which generate approximately 67 % of the world's nuclear electricity are the USA, France, Russia, South Korea, and Germany. Russia was excluded from this study due to data accessibility. Instead,

Japan and the UK were included as Japan experienced the Fukushima nuclear disaster in 2011, and the UK has a long history of using nuclear power for civil purposes. In addition, the countries selected are geographically representative, being situated in Europe, North America, and Asia. Furthermore, nuclear power plant accidents have occurred in all six countries though to varying degrees (SEOMUN XIV Chair Research Report 2011).

Further, nuclear policies before and after the Fukushima accident are compared to examine the extent to which this event affected nuclear policy orientations. Four countries were selected for pre–post comparisons: the UK, USA, Germany, and Japan. These countries were selected from within the larger sample according to data availability and in order to check whether the Fukushima accident influenced overall patterns of nuclear policy orientation.

Data collection

To explore and compare nuclear energy policy frames in the six countries, policy discourses from top-level decision-makers were used as text data for analysis. More specifically, formal speeches by top-level decision-makers about energy policy were utilized. These represent an appropriate source of data, as based on van Dijk's (1977) definition, policy discourses can be seen to be comprised of policy addresses, speeches, and dialog about policy issues.

Methodologically, it is important to show the individual texts to be representative of the nation's policy, because "one official's speech … is likely to be slightly … different from that of another official, even if they belong to the same administration" (van Eeten 2007: 253). This difference can be minimized by using the most representative or collective level of speeches, which usually come from the President, Prime Minister, or Minister of the energy-related department. Speeches from these sources can be seen as representative of national energy policy, rather than an individual perspective. In order to further reduce bias related to the audience, speech writer, or other factors, multiple speeches over a period of time are analyzed.[4]

This study used formal speeches made before and after the March 2011 Fukushima accident, the most critical event in recent years, which had the potential to influence the orientation of nuclear power policy. More specifically, events in Fukushima may have clarified nuclear energy policy orientations; if a government maintained a positive stance toward nuclear power despite the accident, this would highlight the extent to which they wanted to maintain nuclear power as their main electricity source and vice versa. In addition, although their orientations are different in nature, displays of sympathy or concern following the accident could be a starting point for policy convergence.

Specifically, this study analyzed the speeches and addresses of top-level policy-makers in the six countries. These documents were collected from official government websites; researchers used "nuclear" and "energy" as keywords to search for appropriate speeches to analyze within the time range of June 2009–September 2013. Text data were retrieved from each country's national archives, and after reading all of the speeches, extracts were selected for analysis. Excerpts were chosen according to the following criteria: paragraphs

[4] For example, in the case of Germany, excerpts from an energy summit speech (April 15, 2011) and an interview with *Zeit* (May 12, 2011) were combined for post-Fukushima accident frame analysis, while interviews with *FAZ* (February 25, 2010), *Bild am Sonntag* (June 13, 2010), *Frage* (July 7, 2010), *Süddeutsche Zeitung* (September 29, 2010), and *Focus* (November 8, 2010) were combined for pre-Fukushima accident frame analysis.

containing (1) keywords such as nuclear and energy, (2) discussion of policy orientation, and (3) discussion of policy opinions regarding the Fukushima accident. Then, these parts were combined into a text for semantic network analysis (see Appendix 5).

Measurements

For the purpose of network analysis, texts were coded into nodes (i.e., concepts or words) and ties between a pair of nodes (i.e., co-occurrence within a sentence and/or paragraph), which resulted in an nxn matrix. In conducting semantic network analysis, it is necessary to avoid the subjective influences of the author (Paranyushkin 2011). As such, to understand the relationships between concepts in the text, the objective meaning of the concepts should be applied, rather than subjective meanings suggested by the author because the structure of the text appears more clearly when the meaning is neutralized (Derrida 1978). This study regards the same concepts across the speeches to maintain the same meaning. For example, nuclear energy or energy security in the US speech delivers the same meaning as in Germany or Japan, as the top-level decision-makers in this study are government representatives and not likely to use subjective meaning of concepts in their formal speeches. More specifically, excerpts from all 45 texts were preprocessed following the steps suggested by Danowski (1993) and Paranyushkin (2011, 2012). This involved removing all the stopwords (e.g., a, the, is), normalizing past and future tenses, and transforming semantically connected terms into a representative word. In order to conduct these steps, AutoMap software was used, as it was developed for the purpose of preprocessing texts for network analysis (Carley et al. 2007, 2011).

Ties are defined as the co-occurrence of concepts within a limited range of text such as a clause, sentence, paragraph, or the whole text. This study limited the range of co-occurrence to a sentence because, by definition,[5] a sentence is a group of words made to deliver meaning. Thus, words in a sentence may form a node or be connected together as they are made to impart the same point. It is important to note that ties are undirected because they are based upon co-occurrence. When two words occur consecutively, they are considered to be connected.[6] For the actual analysis, two programs were used: Gephi for the modularity analysis and UCINET to calculate the degree and betweenness centralization index.

Results

Description of network structural properties

Table 3 presents the structural properties of the six countries' networks. First, network size (i.e., number of nodes and ties) varies across the countries from the largest network of France to the smallest network of Japan. However, structural properties of network, such as the average degree per concept, network diameter, and average path length, do not differ to any great extent.

Second, while there is relatively little variation in the degree centralization index, there are large differences in the betweenness centralization index. In the USA and Germany, the

[5] The following definition of sentence was used: "a grammatical unit consisting of one or more words that are grammatically linked. A sentence can include words grouped meaningfully to express a statement, question, exclamation, request, command or suggestion" (http://en.wikipedia.org/wiki/Sentence_(linguistics).

[6] A coding example is illustrated in Appendix 4.

Table 3 Network properties[a]

Characteristics	USA	UK	Germany	France	Japan	Korea	Integrated
Nodes	231	527	318	642	257	267	516
Ties	331	914	507	1,002	397	392	1,770
Average degree	2.87	3.47	3.19	3.12	3.09	2.94	6.86
Network diameter	13	11	16	14	15	15	7
Average path length	4.886	4.117	5.683	5.267	4.548	4.672	3.146
Density	0.012	0.007	0.010	0.005	0.012	0.011	0.013
Component	2	1	4	2	1	1	1
Degree centralization index	2.01 %	1.92 %	2.04 %	1.67 %	1.92 %	1.53 %	1.17 %
Betweenness centralization index	47.24 %	31.43 %	51.52 %	20.97 %	35.38 %	38.96 %	27.63 %
Modularity (total # of community)	0.628 (18)	0.572 (19)	0.684 (26)	0.651 (20)	0.621 (15)	0.618 (13)	0.403 (12)
Nodes of first largest community (% of nodes)	32 (13.9)	55 (10.4)	38 (11.9)	61 (9.5)	31 (12.1)	39 (14.6)	92 (17.8)
Nodes of second largest community (% of nodes)	27 (11.7)	49 (9.3)	33 (10.4)	51 (7.9)	28 (10.9)	30 (11.2)	84 (16.3)
Nodes of third largest community (% of nodes)	23 (10.0)	47 (8.9)	31 (9.7)	43 (6.7)	23 (8.9)	23 (8.6)	57 (11.0)

[a] Unit is the number of words

highest ranked concepts according to betweenness centrality are "nuclear" and "energy," respectively, and these terms are dominant in that approximately half of all the flows between concepts are dependent upon these words. In contrast, the highest ranked concepts by betweenness centrality in the UK and France (i.e., "will" and "nuclear," respectively) charge only one-fifth of all meaning flows in their networks.

Third, since modularity is high across all texts, it can be said that the networks are partitioned by tightly knit communities (i.e., dense connections *within* communities, but sparse connections *between* communities).

In the networks of the USA, UK, France, and Korea, "nuclear" and similarly "nuclear-power plant" in that of Japan turned out to be the most influential concept in terms of betweenness centrality, whereas "energy" is the most influential concept in Germany. These are the concepts that connect different communities within the respective networks and therefore play a bridging role. It is important to note that the same concepts were found to be the most influential in the tests of the UK, USA, Germany, and Japan prior to the Fukushima accident. Appendix 2 reveals there to be relatively little variation in the network properties for these countries prior to the Fukushima accident.

Nuclear energy policy frames of the six countries

Table 4 presents the major subgroups of the concept networks in the six countries after the Fukushima accident. The policy arguments on nuclear energy in the USA can be summarized as "Nuclear energy as a clean source of electricity generation" in the largest community, while the second largest community suggests that "Nuclear power plant would unlock civil commitment and demands." Dealing with the other countries in turn, the largest community in the UK appears to be arguing that "The UK should build new nuclear projects for the energy market and economy," while the second largest community suggests that the "government will decarbonize the power sector through the nuclear industry." In Germany, the largest communities put forward the case that "The consensus for the future is that Germany will invest in renewable energy technology rather than nuclear," and that "For nuclear power plants it is time to decide whether to extend the expiration plan," respectively. The largest community in France suggests hesitant support for nuclear power. In particular, that "Nuclear energy has risks but provides choice for (industrial) sector interests and energy security" and that "(Nuclear) electricity at the right safety level boosts the economy and competitiveness." In Japan, the policy argument in the largest community can be summarized in the phrase "Japan will take responsibility and meet expectations based on fundamental decisions," while there is also a strong sentiment that "Japan should boost cooperation with relevant countries." The arguments of the two main communities in Korea are that "Growth in energy demand contributes to demand for alternatives and (energy) independence" and "Korea makes efforts for the safety of future nuclear use with global cooperation."

By examining degree and betweenness centrality of the concepts in terms of structural role in the concept networks, salient concepts can be identified as having international influence (i.e., they play a hub or bridging role in more than two countries). "Nuclear" plays a hub or meaning circulation role in the network of all of the countries with the exception of Japan. While "energy" plays a central role in the USA, Germany, France, and Korea, it is more important as a local hub in Japan and is relatively less influential in the UK. "Will" plays a hub role in UK, Japan, and France, and "new" can be seen to play a hub role in the USA and the UK. Although "safety" also plays a hub role in Korea, in Japan it is most prominent as a local hub. "Nuclear power plant" and "nuclear power" are

Table 4 Influential concepts in the four largest communities of the six countries

Community	USA	UK	Germany	France	Japan	Korea
First largest community	**Nuclear**, **Energy**, Clean, Electricity, Generation, Source, Have_been	**UK**, **New**, **Nuclear**, Energy, Market, **Build**, Economy, Time, Project	**Nuclear**, **Renewable**, **Energy**, Technology, Germany, Will, Invest, Future, Consensus	**Nuclear**, **Energy**, Risk, Security, Supply, Interest, Choice, Industry, Sector	**Japan**, **Will**, Expectation, Year, Responsibility, Fundamental, Decision	**Energy**, Alternative, Growth, Contribute_to, Independence, Demand
Second largest community	Nuclear_power_Plan, Unlock, Commitment, Civil, Demand	**Will**, **G**overnment, Renewable, Coal, Nuclear, Industry	Nuclear_power_plant, Expiration, Decision, Time, Extend, Plan	**France**, Electricity, Economy, Country, Competitiveness, Safety, Level, ASN	Country, Plant, Cooperation, Hold, Relevant	**Nuclear**, **Safety**, Global, Future, Effort, Cooperation
Third largest community	Climate, Change, Contribute_to, Future	Business, Plan, Global, Interest, Recognize, Opportunity	Minister, Party, Discussion, **Have_been**, Challenge, Environment	Future, Challenge, Economic, Cost, Issue	Nuclear_power, Energy, Policy, Security, Promote, Generation	Korea, Will, Confidence, IAEA, Peaceful, Use
Fourth largest community	Safety, Power, Ensure, Industry, Build (20)	Oversea, Investment, Country, Potential, International, Enhancement (39)	Nuclear_power, Electricity, Generation, Supply (27)	Strengthen, International, Cooperation, Regulatory, Standard (37)	Safety, New, Standard, Reform, Plant, Policy (20)	Public, Understanding, Communication (22)

Bold indicates top ranking concepts both in degree and betweenness centrality, which means that these words play a meaning circulation role in concept networks of each country

Parentheses indicate the number of concepts in a community

bridging concepts that aid meaning circulation in Japan, but in Germany the same concepts act more as local hubs. Several terms can be identified as influential in single countries. For example, in Germany, "consensus" is a bridging concept that connects communities, and "renewable" seems to play a hub role. "Accident" plays a bridge role in Korea, while "reactor" plays a hub role in France, and "clean" and "nation" play hub roles in the USA.

By combining influential concepts with subgroups, it is possible to identify national nuclear energy policy frames. Dealing with the USA first, it appears that nuclear energy is perceived as a clean source of electricity that can be unlocked through the development of techniques to improve safety. In the UK, the government sees nuclear power as meeting the needs of the energy market and providing opportunities for economic growth based on partnerships between the UK government and industry, as well as overseas investment. Although energy needs are an important concern in Germany, there is a growing consensus that the time has come to phase out nuclear energy and to invest in renewable energy technologies. Interestingly, the safety of nuclear power is not a high-ranking concept in Germany, although "disaster" is. The frame in France is mixed as it contains risk and an awareness of costs and that a decision must be made, but also discussion of the benefits of nuclear power in terms of energy security and the economy. In Japan, there is an awareness of the need to be responsible as well as the need to consider nuclear safety for international cooperation. Yet, nuclear energy is still seen as an important means of promoting energy security. The Korean government sees energy independence and nuclear safety as central, and there is discussion of past and potential accidents. Simultaneously, there are efforts to strengthen the nation's capacity to provide nuclear power, as well as to promote confidence in nuclear energy safety through putting events into a global context and emphasizing the role of the IAEA.

Through comparing policy arguments across the six countries, similarities and differences between the frames can be identified. In terms of similarities, safety concerns appear to be shared by all of the countries, although in Germany the talk is of disaster. With the exception of Japan, there is a particular concern about the nuclear concept itself and whether it presents the best way forward, as seen with the high ranking of "nuclear" for both degree and betweenness centrality in five of the six countries. At the same time, there is also an awareness of the potential of nuclear power to meet needs for energy security. Turning to the differences, it appears that Germany has diverged the most, as it is concerned to move out of nuclear energy, while the other countries have maintained their interest. However, the motivations driving this interest vary. Whereas France and the UK are particularly interested in the economic benefits, the USA, Japan, and Korea see nuclear power more as a way of meeting energy needs.

Comparison of nuclear energy policy frames before and after the Fukushima accident

For the UK, USA, Germany, and Japan, comparisons were made to examine the differences in policy arguments before and after the Fukushima accident. Appendix 3 presents the major subgroups of the concept networks prior to the Fukushima accident. In the USA, the largest community posits that "as nuclear industry energy sources grow, this demands expertise and leadership." The second community indicates that "nuclear power plants will create more jobs for the country than plants that use coal fuel." In the largest community in the UK, the policy argument can be summarized as "there is potential for companies to create energy supplies and relieve the fuel challenge," whereas in the second community the implication is that "the policy is to build nuclear capacity as industry is willing to make new investments." In Germany, the largest community states "we have long planned and

Table 5 Comparisons of influential concepts before and after the Fukushima Accident for Four Countries

Country	Same	More influential before	More influential after
Germany	Energy, Nuclear_power, Renewable	Scenario, Bridge, Difference, Will	Consensus, Extension, Issue, Disaster, Have_been
UK	Nuclear, Industry	Carbon, Investment, Role, Decommission, Emission, Waste	New, Build, Opportunity, Government, Benefit, Business
Japan	Nuclear, Cooperation	Peaceful, International_community, Continue, Lead_to, Reduction, Advance	Safety, Fundamental, Reform, Electricity, Contribute_to, Market
USA	Nuclear, Energy, Clean, Plant, Safety	Expert, Investment, Finance, Job	Climate, Change, Commitment, Contribute_to, Demand

decided to significantly expand and extend the networks we talk to." In the second largest community, the argument is that "we have reached the end of the nuclear age so the policy is to quickly promote renewable energy." In Japan, the largest community seemingly argues for "strengthened commitment to nuclear materials as a sign of our energy security around the world," while the second community is keen to point out that "foreseen and actual CO_2 emission levels from stations have been established."

Table 5 compares influential concepts before and after the Fukushima accident for the four countries. Despite the Fukushima accident, "Nuclear Energy" maintained the same level of importance in the USA, as did "Nuclear Industry" in the UK, and "Renewable Energy" in Germany, while "Cooperation" was still important in Japan. However, there are also differences. In the USA, while "Nuclear Energy" was related to the concepts "Investment" and "Job" before the accident, it was connected with "Climate" and "Change" after the accident. In the case of Japan, while "Nuclear" and "Nuclear-power" were described with the concepts "Peaceful" and "Energy" before the accident, the same words were later connected with "Safety" and "Energy." The replacement of "Bridge" with "Disaster" and "Consensus" in Germany suggests that Fukushima helped to galvanize opinion against nuclear energy. In the UK, change can also be seen, albeit toward opportunities the nuclear industry can bring.

Accordingly, it can be noted that the policy arguments after the Fukushima accident, to a large extent, are similar to those before the accident. Displaying strong path dependency, the USA has seen nuclear energy as a clean energy source and a means for boosting economy, irrespective of the Fukushima accident. While the US government framed nuclear energy and nuclear power plants mainly in terms of economic benefits before the accident, it subsequently tried to re-frame them in terms of an alternative to reduce greenhouse gas emissions. Showing a similar degree of path dependency, the UK continued to be interested in nuclear energy from the perspective that the nuclear industry could potentially help address fuel challenges, while Germany maintained a strong interest in environmental concerns, and Japan energy security. There are also some differences in the way that the decommissioning of power plants was no longer referred to in any of the UK government's key policy arguments, although even prior to the Fukushima accident this was accompanied by cost considerations. In Germany, a swift move away from nuclear

energy can be detected with the dropping of terms such as "bridging technology" in favor of "expiration" and "investment in renewable energy." In Japan, discussion of CO_2 emissions and the role of the private sector were no longer included in the largest communities as the arguments begun to focus more on responsibility and safety.

Exploring shared meanings among the six countries

This section explores the integrated semantic network in order to (1) identify the overall nuclear policy frames, (2) compare these with policy frames from the six countries, and (3) find shared meanings among the six countries. For the integrated network, the top 30 salient concepts according to both degree and betweenness centrality are ranked in Table 6. "Nuclear," "Energy," and "Will" are the most influential and meaning circulating concepts both before and after the Fukushima accident. This indicates that policy arguments are primarily concerned with discussion of the nuclear concept and how they intend to meet energy needs. Other concepts such as "Investment," and "Nuclear-Power" maintain their influence in both tests. As expected, the importance of "Safety" increases after the accident. In addition, "Electricity" and "Challenge" also become relatively more influential. Before the accident, "Renewable," "Carbon," "Security," and "Emission" were relatively important concepts, but after the accident, these words become less influential. Concepts such as "Industry," "Build," "Continue," and "Technology" play the role of local hubs after the accident because they are relatively high in degree centrality, but lower in betweenness centrality. This suggests that continuing to develop nuclear power plants and associated technology is also an important policy argument within the integrated network. Finally, concepts that bridge communities include "issue," "plan," "security," and "economy." This highlights the extent to which governments need to be seen to have clear strategies to maintain energy security and economy, particularly as "safety" and "investment" are also high-ranking concepts.

The most influential concepts in the local communities of the integrated network are summarized in Table 7. The argument in Community 1 can be understood as suggesting that "The UK remains interested in continuing the program to build and use new plants to enhance the sector and industry, and supply nuclear security." In Community 2, the argument can be summarized as "Progress in this area to meet these goals will improve capability and be a better way to provide benefits for the economy, country and people." Community 3 appears to support nuclear as a clean energy source: "The policy is to secure considerable investment from business to develop nuclear power systems with the potential to ensure clean and safe electricity generation as an energy resource," while Community 4 is concerned more with energy security: "Sharing lessons from the Fukushima accident in Japan, it is time to decommission the expired and this is the best position to restart and extend, there is a responsibility to protect nuclear power plants in the area." In Community 5, the argument is that: "Serious talk about problems can increase consideration of needs and focus on prospects." Clean energy is again emphasized in Community 6: "The conclusion is that there are limitations to fossil and carbon fuels and we support the implementation of an exit," while similar arguments are made in Community 7: "Today we launch strong efforts to enhance our contribution to the question of how to mitigate climate change." In Community 8, the emphasis is more on nuclear safety: "We seek public understanding through reviewing and communicating the dangers and peaceful uses." Communities 9 and 10 are of the same size and are both concerned with sustaining economic growth. Although Community 9 emphasizes the private sector: "The

Table 6 Top 30 ranking concepts by degree and betweenness centrality (integrated network)

Rank	After the Fukushima accident		Before the Fukushima accident	
	Betweenness centrality	Degree centrality	Betweenness centrality	Degree centrality
1	Nuclear	Nuclear[a]	Nuclear	Nuclear[a]
2	Energy	Energy[a]	Energy	Energy[a]
3	Will	Safety[a]	Will	Will[a]
4	Safety	Will[a]	Nuclear_power	Nuclear_power[a]
5	Nuclear-power-plant	New	Japan	Japan[a]
6	Japan	Nuclear_power_plant	Investment	Investment[a]
7	UK	Japan	Carbon	Carbon[a]
8	New	Investment	Security	Security[a]
9	Investment	Nuclear_power	Level[b]	Role[c]
10	Nuclear-power	Government	Industry	Ensure[c]
11	Country	UK	Renewable	Industry
12	Government	Country	Waste	Generation[c]
13	Electricity	Electricity	Emission[b]	Renewable
14	Issue[b]	Industry[c]	Role	Power
15	Have_been	Build[c]	Manage	Level
16	Plan[b]	Have_been	Ensure	Low[c]
17	Challenge	Challenge	Clean[c]	Sector
18	Renewable[b]	Decision	Plan[b]	Waste
19	Year	France	Generation	Manage
20	Decision	Continue[c]	Include	New[c]
21	Sector	Sector	Power	Emission
22	Security[b]	Technology[c]	Plant[b]	Cooperation[c]
23	Time	Global	Progress	Include
24	Economy[b]	Enhancement	Mutual	Operation
25	France	Provide	Increase	Plan
26	Global	Plant	Protection	UK
27	Build	Generation	Fuel	Bridge
28	Needs	Security	New	Peaceful
29	Technology	Renewable	Company	Technology
30	Industry	Plan	Environment	Use

[a] Hub, meaning circulation

[b] Bridging between communities

[c] Local center (local hub)

government choice is to plan to promote the greatest private sector commitment and to consistently advance the market over the long term for citizens," Community 10 is more concerned with growth and jobs generally: "Fundamentally, this is a global opportunity for discussions to consider management and how to improve economic growth, work and jobs." Community 11 stresses that: "There is a community consensus on renewables and a decision to reduce the level of risk from coal and gas power plants and CO_2 emissions." In Community 12, nuclear safety is reflected upon: "The disaster strengthened progress in

Table 7 Influential concepts in the local communities (integrated network)

Community	Influential concepts
Community 1 (92)	Nuclear UK new sector security build industry program interest international plant use enhancement supply continue take_place remain
Community 2 (84)	Way better goal people will country provide benefits progress improvement capability area meet economy
Community 3 (57)	Energy investment nuclear_power electricity ensure generation develop potential policy safe clean source considerable secure business system have_been
Community 4 (42)	Japan nuclear_power_plant decommission time Fukushima extension accident restart expiration area lesson position responsibility best share protection
Community 5 (37)	Needs consideration prospect talk_to problems serious increase focus
Community 6 (32)	Fossil fuels limitation exit support implementation conclusion carbon
Community 7 (27)	Question climate effort contribute_to change launch today enhance strong mitigation
Community 8 (25)	Public understanding communication danger Korea review peaceful seek
Community 9 (24)	Market private_sector US government plan commit long-term promote high citizen choice consistently greatest advance
Community 10 (24)	Global opportunity economic work oversea job discussion growth consider management improve fundamental
Community 11 (23)	Risk reduce Germany decision global coal gas power_plant CO_2 emission renewable consensus information level community
Community 12 (19)	Safety IAEA standard strengthen regulatory progress disaster world cooperation commitment
Community 13 (16)	Force technology operators ASN[a] help facility material assessment policy independence audit training element recommendation skill response
Community 14 (14)	France cost control challenge material future issue reason price objective measure

Parentheses indicate the number of concepts in a community

[a] ASN nuclear security agency of France

IAEA and world cooperation as well as commitment to regulatory and safety standards," and this is also the case in Community 13: "An element of the policy response is to recommend independent assessment and audit of facilities and help with technology and training of skilled operators." Finally, in Community 14, economics is again the primary concern: "In France the challenge and objective is to control the material price issue for future cost measure reasons."

Finally, through combining the centrality analysis (Table 6) with the investigation of the network substructures (Table 7), the overall policy frame can be identified. In the wake of the Fukushima accident, for the countries with nuclear power programs, the rigorous debates over nuclear energy became entangled with three issues: public attitudes toward nuclear energy, the security of energy supplies, and the reduction in greenhouse gas emissions (Corner et al. 2011; Birmingham Policy Commission 2012). Faced with this new situation, all six countries had to find solutions to simultaneously tackle the three issues. More generally, each country was also in the process of recovering from economic recession or attempting to sustain economic development.

Each of the six countries focused on different aspects of nuclear energy debates arising from the Fukushima accident and, thus, framed its own nuclear energy discourse. Yet,

comparing the overall policy frame with sub-frames of the six countries, shared or overlapping meanings can be narrowed down to four main nuclear energy policy frames (i.e., the energy security frame, clean energy frame, economic growth frame, and nuclear safety frame). As presented in Table 8, the 14 major policy arguments identified through analysis of local communities in the network can be situated within these four frames.

As can be seen in Table 9, for the USA, UK, Germany, and Japan, the main four frames prior to the Fukushima accident were similar to the post-Fukushima frames. Interestingly, while the accident did appear to impact the frames, the effects have not been straightforward nor led to convergence. The UK showed some concern for nuclear safety before the accident, but this was outweighed by cost considerations. Following events in Fukushima, the UK framed nuclear energy policy exclusively in terms of economic growth and clean energy, with more emphasis on the former. One explanation could be that the UK government sought to counter the widespread negative publicity. In Germany, the framing of nuclear energy policy continued to be defined by clean energy. However, as discussed above, there was a shift away from arguments for using nuclear energy as a stop-gap measure; the need for renewable energy supplies became more pressing. In Japan, prior to the Fukushima accident, a range of policy frames were utilized to express support for nuclear energy, yet after the accident the clean energy and economic growth frames were minimized as government focused on energy security and nuclear safety. The USA approached nuclear energy mainly from a clean energy perspective with some consideration for energy security and economic growth before the Fukushima accident, and this remained largely the same afterwards.

Still, there are shared meanings post-Fukushima. With the exception of Germany, the countries all appear to believe that nuclear can promote their energy security. Germany is joined in its interest in clean energy by the USA, UK, and Korea, although within the latter group of countries the discourse reflects their energy security concerns. There was also a shared interest among the UK, France, USA, and Korea in increasing economic opportunities through building the nuclear industry and technologies to provide energy. Nuclear safety remains a key concern in Japan and Korea where there is interest in cooperation to strengthen regulatory standards.

Discussion and conclusion

This study has sought to contribute to the comparative literature on nuclear energy policy and framing, as well as to highlight the utility of semantic network analysis at identifying policy frames. While other studies have examined the framing of nuclear power among citizens (Bickerstaff et al. 2008; Corner et al. 2011), we have illustrated how leading policy-makers have framed nuclear energy policy in six major nuclear producers in the aftermath of the Fukushima accident. We also compared policy frames in four of the countries before and after events in Fukushima to examine the effects of the accident.

In doing so, we have highlighted both similarities and differences between the countries. Under the changed policy environments after the accident, all the countries had to develop their own nuclear policy frames while focusing to varying extents on three main pillars of issues: increasing public trust in government and the nuclear industry, enhancing the security of energy supplies, and meeting their own CO_2 reduction targets. At the same time, the countries had to negotiate recovery from the economic crisis. More specifically, as a leader in the world renewable energy market, Germany re-emphasized the clean energy frame. Abandoning nuclear power as a "bridging technology," it decided to phase

Table 8 Similarities between the integrated and individual networks (after the Fukushima accident)

Policy frames	Policy arguments from communities	USA	UK	Germany	France	Japan	Korea
Energy security frame: meeting the growing energy needs	Progress in this area to meet these goals will improve capability and be a better way to provide benefits for the economy, country and people	○			△	○	△
	Sharing lessons from the Fukushima accident in Japan, it is time to decommission the expired and this is the best position to restart and extend, there is a responsibility to protect nuclear power plants in the area				△	○	
	Serious talk about problems can increase consideration of needs and focus on prospects		△	△	△	△	△
Clean energy frame: contributing to the mitigation of climate change	The policy is to secure considerable investment from business to develop nuclear power systems with the potential to ensure clean and safe electricity generation as an energy resource	○	△				△
	The conclusion is that there are limitations to fossil and carbon fuels, and we support the implementation of an exit			○			
	Today we launch strong efforts to enhance our contribution to the question of how to mitigate climate change		△	△			
	There is a community consensus on renewables and a decision to reduce the level of risk from coal and gas power_plants and CO_2 emissions		△	○			
Economic growth frame: sustaining economic development	The UK remains interested in continuing the program to build and use new plants to enhance the sector and industry, and supply nuclear security		○				
	The government choice is to plan to promote the greatest private sector commitment and to consistently advance the market over the long term for citizens	△	△		△		
	Fundamentally, this is a global opportunity for discussions to consider management and how to improve economic growth, work, and jobs		△		△		△

Table 8 continued

Policy frames	Policy arguments from communities	USA	UK	Germany	France	Japan	Korea
	In France, the challenge and objective are to control the material price issue for future cost measure reasons				○		
Nuclear safety frame: reducing public opposition to nuclear power	We seek public understanding through reviewing and communicating the dangers and peaceful uses					○	△
	An element of the policy response is to recommend independent assessment and audit of facilities and help with technology and training of skilled operators	△				△	△
	The disaster strengthened progress in IAEA and world cooperation as well as commitment to regulatory and safety standards					△	△

○: The policy frame is almost the same

△: The policy frame is similar

Table 9 Similarities between the integrated and individual networks (prior to the Fukushima accident)

Policy frames	Policy arguments from communities	USA	UK	Germany	Japan
Energy security frame	The plan is to use nuclear and renewables to forward manage energy supplies	△			△
	Important role of companies in promoting energy security needs to be built		△		
Clean energy frame	So far, regulation has achieved percentage reductions and changed electricity generation for our shared environment goals			△	△
	Maintain progress and increase confidence about future scenarios and establishing emission level		△	△	△
	Consideration for the dependence on fossil fuels should be limited	△	△		
Economic growth frame	Ensure investment for industry to deliver on its commitment to appropriate reactor construction and design and efforts to provide skills for the operator workforce		△		
	We will challenge the private sector to drive advances and capacity extension in the long term		○		○
	The low-carbon sector has potential including low prices and job creation, but continues to face strong barriers	△	△		
Nuclear safety frame	Mutual respect and cooperation can lead to agreement on the matter of safeguarding materials and growth in this area				○

Table 9 Similarities between the integrated and individual networks (prior to the Fukushima accident)

Policy frames	Policy arguments from communities	USA	UK	Germany	Japan
	The government has long decided to use technology for peaceful nuclear power plants for the public				○
	Protection through decommissioning radioactive waste disposal operations has costs		△		

○: The policy frame is almost the same

△: The policy frame is similar

out nuclear plants just after the Fukushima accident. The USA and Japan have framed the issues primarily in nuclear safety and energy security terms, although the clean energy frame is also important in the USA. The UK and France are particularly interested in the economic growth frame and have not sought to emphasize the nuclear safety frame, which has been given priority in Korea. These findings can be discussed in terms of the implications for nuclear energy policies in the countries with nuclear programs.

First, each country's nuclear energy policies displayed strong path dependency, even after the Fukushima accident. It would appear that a movement away from existing energy policy patterns was limited to a large extent by a mixture of two path-dependent constraints: economic growth and energy security. These constraints insulated nuclear policy frames from sweeping changes in each country, since to diverge from established paths could result in unpredictable costs for energy security and national economy (Vivoda 2012; Scholvin 2014). In this regard, the Fukushima accident did not substantially affect the paths of nuclear energy discourses. Even Japan's energy policy is still seen to be on the same path following the disaster (Vivoda 2012). Rather than making a drastic decision to close nuclear plants as in Germany, the other countries focused on enhanced safety measures according to the advice of international organizations such as the UN, IAEA, and WNO. Still, as revealed in the analysis, the nuclear energy frames were influenced more by domestic demands rather than international considerations.

Second, nuclear energy was strategically framed in relation to renewable energy sources in each country. Though nuclear energy was viewed as a green energy with the potential to help mitigate greenhouse gas emissions, these claims have not been thoroughly examined when compared to other renewable energy sources. On the other hand, a variety of technical and economic problems need to be solved before renewable energy sources are rolled out on a large scale. Given this uncertainty, nuclear power could be framed as a viable option for reducing CO_2 emissions from fossil fuels (EIA 2013). In this regard, the UK government has emphasized the role of nuclear energy in mitigating climate change, a strategy which was successful in shaping supportive attitudes among the public.

Third, given the degree of public interest and participation in energy policy governance, it is important to understand the debate over nuclear energy not just from technological perspectives, but also within its various contexts. This should be the most important consideration for nuclear power, which has been the subject of public skepticism and low trust. The results of the present study can feed into this process; nuclear energy can serve either as a bridge to an all-renewable economy as in Germany and the USA or as a long-term solution by itself as in the UK (Sastry and Siegel 2010), depending upon the economic, political, and environmental contexts of each country. Therefore, it is vital for each government to formulate its own national frame on nuclear energy which can resonate with

other energy sources. As the countries with nuclear programs continue to debate the future of their energy policies and programs, the ways in which policy frames are formulated helps determine their future direction. In particular, frames should be constructed in terms of a future energy mix that contributes to CO_2 reduction, to energy security, and to economic growth, while enhancing nuclear safety.

Fourth, drawing on scientific arguments could be helpful in framing national discourse on nuclear energy and its safety, particularly in aiding general publics' sense making (Vink et al. 2012). A reason for this is because energy and nuclear power concerns differ from other policy issues in that they can be "epistemologically distant" from everyday experiences (Carolan 2004; Vink et al. 2012). As nuclear safety has come to the fore post-Fukushima, pronuclear countries have faced concerns from citizens regarding whether nuclear power plants are safe enough to be maintained. In this situation, IAEA safety guarantees have been used strategically to strengthen policy legitimacy, as in Korea. Still, there is space for scientific arguments that seek to improve public understanding and lead to a more informed citizenry.

The other major aim of the study was to present the usefulness of semantic network analysis for identifying policy frames. In particular, this study attempted to combine quantitative and qualitative frame analysis techniques through a concept network-based frame analysis. The results indicate that identifying frames through semantic network analysis could contribute to a better understanding of how similar and/or different the policy orientations of chief policy-makers are. Through this methodology, we could not only objectively identify the central words in each country's energy policy discourse, as in quantitative frame analysis, but were also able to analyze the hidden meanings of the community of words in an interpretive way as in qualitative frame analysis (Doerfel 1998; Carley 1997a, b; Danowski 1993; Paranyushkin 2011, 2012). As such, semantic network analysis represents a valuable methodology which can combine the strengths of other types of frame analysis in the concrete identification of frames generated by policy actors.

Despite these contributions, the limitations of semantic network analysis need to be addressed. Most of all, validation can be difficult for densely connected large-scale networks (Diesner 2012). More specifically, techniques for text preprocessing, node identification, and link construction, which must be decided before mining network structure from text data, could strongly influence the structure of resulting networks; different methods may produce different results (Carley 1993). This indicates that techniques for semantic network analysis should be selected with care and be closely aligned with research questions and objectives. This study also applied undirected ties among words based on co-occurrence. Corman et al. (2013) argued, however, that directional links would provide a more accurate description of meaning than nondirectional links. This issue needs to be addressed more completely in future research. Finally, this study focused on analyzing the policy frames of leading policy-makers at the national level to compare similarities and differences in policy frames among the leading nuclear countries. However, other policy actors such as media and nongovernmental organizations also make policy frames which could influence (inter-)national nuclear energy discourses. Further studies could utilize semantic network analysis with a wider range of actors within a particular country or examine in detail how the audience affects the framing of speeches. In this sense, semantic network analysis can contribute to improved understanding of the different nuclear energy policy frames and attempt to move toward shared goals.

Acknowledgments This work was supported by the National Research Foundation of Korea Grant funded by the Korean Government (NRF-2013S1A3A2055108).

Appendix 1

See Table 10.

Table 10 Comparison of nuclear energy among six countries

Country	Nuclear electricity generation 2012		Reactors operable		Reactors under construction		Reactors planned		Reactors proposed	
			October 2013		October 2013		October 2013		October 2013	
Unit	Billion kWh	% e	No.	MWe net	No.	MWe gross	No.	MWe gross	No.	MWe gross
France	407.4	74.8	58	63,130	1	1,720	1	1,720	1	1,100
Germany	94.1	16.1	9	12,003	0	0	0	0	0	0
Japan	17.2	2.1	50	44,396	3	3,036	9	12,947	3	4,145
Korea	143.5	30.4	23	20,787	5	6,870	6	8,730	0	0
UK	64	18.1	16	10,038	0	0	4	6,680	9	12,000
USA	770.7	19	100	98,951	3	3,618	9	10,860	15	24,000
World	2,346	11	432	371,900	70	73,366	173	187,740	314	356,986

Source: WNA (2014c)

Appendix 2

See Table 11.

Table 11 Network properties: prior to the Fukushima accident[a]

Characteristics	USA	UK	Germany	Japan	Integrated
Nodes	220	240	170	192	249
Ties	310	357	221	265	761
Average degree	2.82	3.06	2.6	2.76	6.11
Network diameter	12	11	17	15	6
Average path length	4.58	4.478	5.341	5.092	2.941
Density	0.013	0.013	0.015	0.014	0.025
Component	2	2	1	2	1
Degree centralization index	1.78 %	2.16 %	2.54 %	2.96 %	2.13 %
Betweenness centralization index	46.57 %	36.88 %	50.61 %	39.23 %	26.51 %
Modularity (total # of community)	0.648 (18)	0.629 (14)	0.650 (12)	0. 688 (13)	0.412 (12)
Nodes of first largest community (% of nodes)	30 (13.6)	30 (12.5)	31 (18.2)	22 (11.5)	41 (16.5)
Nodes of second largest community (% of nodes)	30 (13.6)	29 (12.1)	29 (17.1)	20 (10.4)	34 (13.7)
Nodes of third largest community (% of nodes)	22 (10.0)	25 (10.4)	23 (13.5)	19 (9.9)	28 (11.2)

[a] Unit is the number of words

Appendix 3

See Table 12.

Table 12 Influential concepts in the four largest communities of the four countries: prior to the Fukushima accident

Community	USA	UK	Germany	Japan
First largest community	**Nuclear**, **Energy**, Source, Fuel, Expert, Leader, Grow, Industry (30)	**Energy**, Challenge, Potential, Supply, Fuel, Create, Company, Relieve (30)	**Will**, Significantly, Expand, Current, Network, Talk_to, Extension, Context, Plan, Decide (31)	**Nuclear**, Energy, Security, Material, Strengthen, Commitment, Sign, Around_the_world (22)
Second largest community	**Plant**, Nuclear_power, Will, Year, Generate, Job, Create, Country, Coal, Continue (30)	**Nuclear**, Industry, **Investment**, New, Build, Manage, Capacity, Policy, Willing_to (29)	**Energy**, Renewable, Achieve, Reach, Nuclear, Age, Quickly, Promote, Policy (29)	Level, Emission, Station, Maintain, Actual, Foresee, Biggest, Establish, CO2 (20)
Third largest community	**Clean**, Nautral_gas, Safety, Finance, Provide, Reserve, Transition, Provide (22)	Nuclear_power, **Role**, Provide, Certainty, Clear, Importance, Coalition, Reduction (25)	**Bridge**, Technology, Time, Share, Environment, Realistic, Electricity, Today (23)	**Cooperation**, Area, Mutual, Agreement, Matter, Importance, Assistance, Strategy, Beneficial (19)
Fourth largest community	**Investment**, Oil, Area, Break, Tax, Prioritize, Company, Decision (19)	Low, **Carbon**, Emission, Economy, Lower, Price, Society, Infrastructure, Control (23)	**Scenario**, Difference, Fact, Lead_to, Calculate, Table, Discussion, Solar, Concern (23)	**Will**, Advance, Private_sector, Target, Effort, Attain, Combine, Development (17)
Other key community	Gas, Legitimate, Change, Greenhouse, Climate, Prevent (14)	Waste, Decommission, Long_term, Cost, Activity, Disposal, Operation, Radioactive, Essential (21)	**Nuclear_power**, Plant, Germany, Operation, Call_for, Clear, Replacement (19)	**Peaceful**, Use, **Nuclear_power** Technology, Guarantee, Plant (13)

Bold indicates top ranking concepts both in degree and betweenness centrality

Parentheses indicate the number of concepts in a community

Appendix 4: Example of coding

Original text (a sentence): While nuclear energy has the advantages of being an inexpensive and clean energy source, it is with greater confidence in its safety that it can be more widely used.

Converted to: nuclear energy advantage inexpensive clean energy source greater confidence safety widely use.

Each word is defined as a node. Then, two consecutive words are connected; nuclear-energy, energy-advantage, advantage-inexpensive…. safety-widely, widely-use.

Appendix 5

See Table 13.

Table 13 Data collection for semantic network analysis by the six countries

Country	No. of texts used	Language provided	By whom	Excerpts from	Source (Website)
USA	6 (before)	English	President (Barack Obama)	6 remarks by the President (February 16, March 31, April 2, June 2, September 6, October 25, 2010)	www.whitehouse.gov
	7 (after)		President (Barack Obama)	7 remarks by the President (March 17, March 30, 2011, February 23, March 7, 22, 26, 2012, March 15, 2013)	
UK	6 (before)	English	Minister of State for Energy (Charles Hendry) and Secretary (Chris Huhne)	4 Ministerial speeches (June 16, October 21, 2010, and January 31, March 2, 2011) and 2 Secretary speeches (December 16, 2010, January 24, 2011)	https://www.gov.uk/government/organisations/cabinet-office
	3 (after)		Prime Minister (David Cameron) and Minister of State for Energy (Michael Fallon)	1 Ministerial speech (September 17, 2013) and 2 Prime Ministerial addresses (April 26, 2012, and March 19, 2012)	
Germany	5 (before)	German (translated to English)	Prime Minister (Angela Merkel)	5 Prime Ministerial interviews (February 25, June 13, and July 7, September 29, November 8, 2010)	http://www.bundeskanzlerin.de/Webs/BKin/DE/Startseite/startseite_node.html
	2 (after)		Prime Minister (Angela Merkel)	1 Prime Ministerial speech (April 15, 2011) and 1 interview (May 12, 2011)	
France	4	French (translated to English)	Prime Minister (François Fillon) and President (François Hollande)	1 Prime Ministerial speech (March 8, 2012) and 3 Presidential speeches (September 14, 2012, September 20, October 1, 2013)	http://www.ambafrance-at.org/Surete-nucleaire-extraits-du
Japan	4 (before)	English	Prime Minister (3 by Yukio Hatoyama and 1 by Abe Shinzo)	4 Prime Ministerial speeches (January 18, 2011, April 12, 2010, and June 10, October 26, 2009)	http://www.kantei.go.jp/foreign/index-e.html
	5 (after)		Prime Minister (Abe Shinzo)	5 Prime Ministerial speeches (January 4, February 28, May 3, June 18, and September 7, 2013)	
Korea	3	English	President (1 by Lee Myungbak and 2 by Park Geunhye)	3 Presidential speeches (September 22, 2011, May 9, 2013, and June 29, 2013)	http://www.president.go.kr/president/speech.php

References

Associated Press. (2011). *Germany decides to abandon nuclear power by 2022*. Retrieved May 30, 2011.

Baumgartner, F. R., Boef, S. D., & Boydstun, A. (2008). *The decline of the death penalty and the discovery of innocence*. Cambridge: Cambridge University Press.

BBC News (2011). *Germany: Nuclear power plants to close by 2022*. May 30, 2011. http://www.bbc.co.uk/news/world-europe-13592208

BBC News (2013). French jobless rate climbs to highest level in 15 years. http://www.bbc.com/news/business-22794313

Bickerstaff, K. I. L., Pidgeon, N. F., Poortinga, W., & Simmons, P. (2008). Reframing nuclear power in the UK energy debate: Nuclear power, climate change mitigation, and radioactive waste. *Public Understanding of Science, 17*, 145–169.

Birmingham Policy Commission. (2012). *The future of nuclear energy in the UK*. Birmingham: University of Birmingham.

Bradford, P. (2012). The nuclear landscape. *Nature, 483*, 151–152.

Burgermeister, J. (2009). *Germany: The world's first major renewable energy economy*. Renewable energy world.com. http://www.renewableenergyworld.com/rea/news/article/2009/04/germany-the-worlds-first-major-renewable-energy-economy?cmpid=WNL-Wednesday-April8-2009

Cappella, J. N., & Jamieson, K. H. (1997). *Spiral of cynicism: The press and the public good*. New York: Oxford University Press.

Carley, K. M. (1990). Group stability: A socio-cognitive approach. In W. Lawler, B. Markovsky, C. Ridgeway, & H. Walker (Eds.), *Advances in group processes: Theory & research* (Vol. VII, pp. 1–44). Greenwich, CN: JAI Press.

Carley, K. M. (1993). Coding choices for textual analysis: A comparison of content analysis and map analysis. *Sociological Methodology, 23*, 75–126.

Carley, K. M. (1994). Extracting culture through textual analysis. *Poetics, 22*, 291–312.

Carley, K. M. (1997a). Extracting team mental models through textual analysis. *Journal of Organizational Behavior, 18*, 533–558.

Carley, K. M. (1997b). Network text analysis: The network position of concept. In C. W. Roberts (Ed.), *Text analysis for the social sciences: Methods for drawing statistical inferences from texts and transcripts* (pp. 79–100). Mahwah, NJ: Lawrence Erlbaum Associates, Publishers.

Carley, K. M. (2002). Smart agents and organizations of the future. In L. Lievrouw & S. Livingstone (Eds.), *The handbook of new media: Social shaping and consequences of ICTs* (pp. 206–220). Thousand Oaks, CA: Sage.

Carley, K. M., Columbus, D., Bigrigg, M., & Kunkel, F. (2011). *AutoMap user's guide 2011*. Technical Report, CMU-ISR-11-108, Carnegie Mellon University, School of Computer Science, Institute for Software Research.

Carley, K. M., Diesner, J., Reminga, J., & Tsvetovat, M. (2007). Toward an interoperable dynamic network analysis toolkit. *Decision Support Systems. Special Issue Cyberinfrastructure for Homeland Security, 43*(4), 1324–1347.

Carley, K. M., & Palmquist, M. (1991). Extracting, representing, and analyzing mental models. *Social Forces, 70*(3), 601–636.

Carolan, M. (2004). Ontological politics: Mapping a complex environmental problem. *Environmental Values, 13*(4), 497–522.

Chong, D., & Druckman, J. N. (2007). Framing public opinion in competitive democracies. *American Political Science Review, 101*, 637–655.

Chong, D., & Druckman, J. N. (2011). Identifying frames in political news. In E. P. Bucy & R. L. Holbert (Eds.), *The sourcebook for political communication research: Methods, measures, and analytical techniques* (pp. 238–267). New York: Routledge.

Corman, S., Brewer, G., Ball, H., Fisk, M., Fleischer, K., &Ruston, S. (2013). *A test of semantic text network validity using a false memory paradigm, XXXIII*. In Sunbelt Social Networks Conference of the International Network for Social Network Analysis (INSNA), May 21–26, 2013, Hamburg, Germany.

Corner, A., Venables, D., Spence, A., Poortinga, W., Demski, C., & Pidgeon, N. (2011). Nuclear power, climate change and energy security: Exploring British public attitudes. *Energy Policy, 39*, 4823–4833.

Creed, D., Langstraat, J., & Scully, M. (2002). A picture of the frame: Frame analysis as technique and as politics. *Organizational Research Methods, 5*(1), 34–55.

Daemen, T. J. (1993). The need for liability constraints in successful high-technology development: A comparison of the French and U.S. commercial nuclear programs. *Northwestern Journal of International Law & Business, 13*(3), 684–710.

Danowski, J. A. (1982). Computer-mediated communication: A network based content analysis using a CBBS conference. In M. Burgoon (Ed.), *Communication yearbook 6* (pp. 905–924). Beverly Hills, CA: Sage.

Danowski, J. A. (1993). Network analysis of message content. In G. Barnett & W. Richards (Eds.), *Progress in communication sciences XII* (pp. 197–222). Norwood, NJ: Ablex.

David, P. A., & Rothwell, G. S. (1994). Measuring standardization: An application to the American and French nuclear power industries. *European Journal of Political Economy, 12*, 291–308.

Dayton, D. (2000). Policy frames, policy making and the global climate change discourse. In H. Addams & J. Proops (Eds.), *Social discourse and environmental policy: An application of Q methodology* (pp. 71–91). Cheltenham: Edward Elgar.

de Vreese, C. H. (2005). News framing: Theory and typology. *Information Design Journal & Document Design*, *13*(1), 51–62.

Delmas, M., & Heiman, B. (2000). Government credible commitment to the French and American nuclear power industries. *Journal of Policy Analysis and Management, 20*(3), 433–456.

Derrida, J. (1978). *Derrida: Writing and difference* (A. Bass, Trans.) London: Routledge & Kegan Paul Ltd.

Diesner, J. (2012). *Uncovering and managing the impact of methodological choices for the computational construction of socio-technical networks from texts.* Ph.D. Dissertation, Carnegie Mellon University, Pittsburgh, PA.

Diesner, J. & Carley, K. M. (2004). Using network text analysis to detect the organizational structure of covert networks. In *Proceedings of the North American Association for Computational Social and Organizational Science (NAACSOS) Conference, Pittsburgh, PA*, July, 2004.

Diesner, J., & Carley, K. M. (2005). Revealing social structure from texts: Meta-matrix text analysis as a novel method for network text analysis. In V. K. Narayanan & D. J. Armstrong (Eds.), *Causal mapping for information systems and technology research: Approaches, advances, and illustrations* (pp. 81–108). Harrisburg, PA: Idea Group Publishing.

Doerfel, M. L. (1998). What constitutes semantic network analysis? A comparison of research and methodologies. *Connections, 21*(2), 16–26.

Doerfel, M., & Barnett, G. (1999). A Semantic network analysis of the international communication association. *Human Communication Research, 25*(4), 589–603.

Doerfel, M. L., & Connaughton, S. L. (2009). Semantic networks and competition: Election year winners and loses in U.S. televised presidential debates, 1960–2004. *Journal of the American Society for Information Science and Technology, 60*(1), 201–218.

Doerfel, M. L., & Marsh, P. S. (2003). Candidate-issue positioning in the context of presidential debates. *Journal of Applied Communication Research, 31*(3), 212–237.

DTI. (2007). *Energy white paper: Meeting the energy challenge*. London: Department of Trade and Industry (DTI).

Dunn, W. N. (2003). *Public policy analysis: An introduction* (3rd ed.). Upper Saddle River: Prentice Hall.

EIA. (2013). *International energy outlook 2013*. Washington: U.S. Energy Information Administration.

Entman, R. M. (1993). Framing: Toward clarification of a fractured paradigm. *Journal of Communication, 43*(4), 51–58.

Fischer, F. (2003). *Reframing public policy: Discursive politics and deliberative practices*. New York: Oxford University Press.

Fischer, F., & Gottweis, H. (Eds.). (2012). *The argumentative turn revisited: Public policy as communication Practice*. Durham, NC: Duke University Press.

Freeman, L. C. (1979). Centrality in social networks: Conceptual clarification. *Social Networks, 1*(3), 215–239.

Gamson, W. A., & Mogdiliani, A. (1989). Media discourse and public opinion on nuclear power: A constructionist approach. *American Journal of Sociology, 95*, 1–37.

Goffman, E. (1974). *Frame analysis: An essay on the organization of experience*. New York, NY: Harper & Row.

Green, D. P., & Shapiro, I. (1994). *Pathologies of rational choice theory: A critique of applications in political science*. New Haven: Yale University Press.

Hajer, M. (1995). *The politics of environmental discourse: Ecological modernization and the policy process*. Oxford: Clarendon Press.

Hayashi, M., & Hughes, L. (2013). The policy responses to the Fukushima nuclear accident and their effect on Japanese energy security. *Energy Policy, 59*, 86–101.

Hertog, J., & McLeod, D. (2001). A Multiperspectival approach to framing analysis: A field guide. In S. Reese, O. Gandy, & A. Grant (Eds.), *Framing public life* (pp. 139–161). Mahwah, NJ: Erlbaum.

HM Government. (2013). *The UK's nuclear future*. The UK Government.

Hummon, N., & Doreian, P. (1989). Connectivity in a citation network: The development of DNA theory. *Social Networks, 11*(1), 39–63.
IAEA. (2014). Nuclear safety and security. International Atomic Energy Agency. http://www-ns.iaea.org/
IEE Japan. (2012). *Energy security and challenges for Japan*. Institute of Energy Economics.
Itoh, S. (2013). *Energy security in Northeast Asia: A pivotal moment for the U.S.-Japan Alliance*. Series: Brookings East Asia Commentary.
Jang, H.-Y., & Barnett, G. A. (1994). Cultural differences in organizational communication: A semantic network analysis. *Bulletin of Methodological Sociology, 44*, 31–59.
Joppke, C. (1991). Social movements during cycles of issue attention: The decline of the anti-nuclear energy movements in West Germany and the USA. *British Journal of Sociology, 42*(1), 43–60.
Kim, J. H., Su, T. Y., & Hong, J. (2011). The influence of geopolitics and foreign policy on the U.S. and Canadian media: An analysis of newspaper coverage of Sudan's Darfur conflict. *The Harvard International Journal of Press/Politics, 12*(3), 87–95.
Krippendorff, K. (2004). *Content analysis: An introduction to its methodology*. Thousand Oaks, CA: Sage.
Kwon, K., Barnett, G. A., & Chen, H. (2009). Assessing cultural differences in translations: A semantic network analysis of the universal declaration of human rights. *Journal of International and Intercultural Communication, 2*(2), 107–138.
Lakoff, G. (1996). *Moral politics: What conservatives know that liberals don't*. Chicago: University of Chicago Press.
Laws, D., & Rein, M. (2003). Reframing practice. In M. Hajer & W. Hendrik (Eds.), *Deliberative policy analysis: Understanding governance in the network society* (pp. 172–206). Cambridge: Cambridge University Press.
Lejano, P. L. (2006). *Frameworks for policy analysis: Merging texts and contexts*. New York: Routledge.
Lewicki, R., Gray, B., & Elliott, M. (2003). *Making sense of intractable environmental conflicts: Concepts and cases*. Washington, DC: Island Press.
Lukeš, D. (2007). Discourse-level constructions and frame analysis of policy discourse: Case of evaluation of university teaching. In *New directions in cognitive linguistics, 2nd conference of the UK Cognitive Linguistics Association*, August 27–30 2007, Cardiff, UK.
Majone, G. (1989). *Evidence, argument & persuasion in the policy process*. New Haven, CT: Yale University Press.
Maynard, M. (1997). Opportunity in paid vs. unpaid public relations internships: A semantic network analysis. *Public Relations Review, 23*(4), 377–390.
Moody, J. (2004). The structure of a social science collaboration network: Disciplinary cohesion from 1963 to 1999. *American Sociological Review, 69*(2), 213–238.
Nelson, T., Clawson, R. A., & Oxley, Z. M. (1997). Media framing of a civil liberties conflict and its effect on tolerance. *The American Political Science Review, 91*(3), 567–583.
Newman, M. E. J. (2006). Modularity and community structure in networks. *PNAS, 103*(23), 8577–8582.
Newman, M. E. J. (2010). *Networks: An introduction*. New York: Oxford University Press.
Nohrstedt, D. (2005). External shocks and policy change: Three Mile Island and Swedish nuclear energy policy. *Journal of European Public Policy, 12*(6), 1041–1059.
Palfreman, J. (2009). *Why the French like nuclear energy*. PBS Frontline. Retrieved from http://www.pbs.org/wgbh/pages/frontline/shows/reaction/readings/french.html
Paranyushkin, D. (2011). *Identifying the pathways for meaning circulation using text network analysis*. Published in December 11, 2011, Nodus Labs. Berlin, Germany.
Paranyushkin, D. (2012). *Visualization of text's polysingularity using network analysis*. Published in January 15, 2011, Nodus Labs. Berlin, Germany.
Pidgeon, N. F., Lorenzoni, I., & Poortinga, W. (2008). Climate change or nuclear power—No thanks! A quantitative study of public perceptions and risk framing in Britain. *Global Environmental Change, 18*, 69–85.
Popping, R. (2000). *Computer-assisted text analysis*. London, Thousand Oaks: Sage.
Popping, R. (2003). Knowledge graphs and network text analysis. *Social Science Information, 42*(1), 91–106.
Rice, R. E., & Danowski, J. A. (1993). Is it really just like a fancy answering machine? Comparing semantic networks of different types of voice mail users. *The Journal of Business Communication, 30*(4), 369–397.
Roberts, C. W. (1997). Introduction. In C. W. Roberts (Ed.), *Text analysis for the social sciences: Methods for drawing statistical inferences from texts and transcripts* (pp. 1–8). Mahwah, NJ: Lawrence Erlbaum Associates, Publishers.
Saarikoski, H. (2006). When frames conflict: Policy dialogue on waste. *Environment and Planning C: Government and Policy, 24*, 615–630.

Salisbury, J. G. T. (2001). Using neural networks to assess corporate image. In M. West (Ed.), *Progress in communication science* (Vol. 17, pp. 65–86)., Applications of computer content analysis Westport, CT: Ablex.

Sastry, R., & Siegel, B. (2010). The French connection: Comparing French and American civilian nuclear energy programs. *Stanford Journal of International Relations, 11*(2), 16–27.

Scheufele, D. A. (1999). Framing as a theory of media effects. *Journal of Communication, 49*(4), 103–122.

Schneider, M., et al. (2013). *World nuclear industry status report 2013.* Mycle Schneider Consulting Project.

Scholvin, S. (2014). South Africa's energy policy: Constrained by nature and path dependency. *Journal of Southern African Studies, 40*(1), 185–202.

Schön, D. A., & Rein, M. (1994). *Frame reflection: Toward the resolution of intractable policy controversies*. New York: Basic Books.

Scott, J. (2000). *Social network analysis: A handbook* (2nd ed.). Thousand Oaks, CA: Sage Publications Ltd.

Semetko, H. A., & Valkenburg, P. M. (2000). Framing European politics: A content analysis of press and television news. *Journal of Communication, 50*(2), 93–109.

Seoul Model United Nations XIV (2011). *SEOMUN XIV Chair Research Report.*

Sherblom, J. C., Reinsch, N. L, Jr, & Beswick, R. W. (2001). Intersubjective semantic meanings emergent in a work group: A neural network content analysis of voice mail. In M. West (Ed.), *Progress in communication science* (Vol. 17, pp. 33–50)., Applications of computer content analysis Westport, CT: Ablex.

Sirin, S. M. (2010). An assessment of Turkey's nuclear energy policy in light of South Korea's nuclear experience. *Energy Policy, 38*(10), 6145–6152.

Smith, A. E. (2003). Automatic extraction of semantic networks from text using Leximancer. In *HLT-NAACL 2003 human language technology conference of the North American chapter of the association for computational linguistics: Companion volume* (pp. Demo23–Demo24). Edmonton: ACL.

Smith, A. E., & Humphreys, M. S. (2006). Evaluation of unsupervised semantic mapping of natural language with Leximancer concept mapping. *Behavioral Research Methods, 38*(2), 262–279.

Sowa, J. F. (1992). Semantic networks. In S. C. Shapiro (Ed.), *Encyclopedia of artificial intelligence* (2nd ed., pp. 1493–1511). New York, NY: Wiley.

Srinivasan, T. N., & Gopi Rethinaraj, T. S. (2013). Fukushima and thereafter: Reassessment of risks of nuclear power. *Energy Policy, 52*, 726–736.

Stokey, E., & Zeckhauser, R. J. (1978). *A primer for policy analysis*. New York: Norton & Company.

Stone, D. A. (1988). *Policy paradox and political reason*. New York: HarperCollins Publishers.

Teräväinena, T., Lehtonenb, M., & Martiskainen, M. (2011). Climate change, energy security, and risk—Debating nuclear new build in Finland, France and the UK. *Energy Policy, 39*(6), 3434–3442.

The UK Government. (2013). *Leading the way: The UK's new nuclear renaissance*. https://www.gov.uk/government/speeches/leading-the-way-the-uks-new-nuclear-renaissance

Toulmin, S., Rieke, R., & Janik, A. (1984). *An introduction to reasoning* (2nd ed.). New York: Macmillan Publishing Co., Inc.

Triandafyllidou, A., & Fotiou, A. (1998). Sustainability and modernity in the European Union: A frame theory approach to policy-making. *Sociological Research Online, 3*(1). http://www.socresonline.org.uk/3/1/2.html

UNFCC. (2014). *Background on the UNFCCC: The international response to climate change*. The United Nations Framework Convention on Climate Change (UNFCC). http://unfccc.int/essential_background/items/6031.php

van Atteveldt, W., Kleinnijenhuis, J., & Ruigrok, N. (2008). Parsing, semantic networks, and political authority using syntactic analysis to extract semantic relations from Dutch newspaper articles. *Political Analysis, 16*, 428–446.

van Dijk, T. A. (1977). *Text and context*. London: Longman.

van Eeten, M. M. J. (2007). Narrative policy analysis. In F. Fischer, G. J. Miller, & M. S. Sidney (Eds.), *Handbook of public policy analysis: Theory, politics, and methods* (pp. 251–269). Boca Raton, FI: CRC Press.

Vink, M. J., et al. (2012). Changing climate, changing frames. *Environment Science Policy,*. doi:10.1016/j.envsci.2012.10.010.

Vivoda, V. (2012). Japan's energy security predicament post-Fukushima. *Energy Policy, 46*, 135–143.

Wasserman, S., & Faust, K. (1994). *Social network analysis: Methods and applications*. New York: Cambridge University Press.

WEC. (2012). *World energy perspective: Nuclear energy one year after Fukushima.* World Energy Council.

Wilson Center. (2012). *Going beyond nuclear: New energy security realities for Japan and the United States.* http://www.wilsoncenter.org/event/going-beyond-nuclear-new-energy-security-realities-for-japan-and-the-united-states

WNA. (2014a). *Nuclear power in South Korea.* World Nuclear Association. http://www.world-nuclear.org/info/Country-Profiles/Countries-O-S/South-Korea/

WNA. (2014b). *US nuclear power policy*. World Nuclear Association. http://www.world-nuclear.org/info/Country-Profiles/Countries-T-Z/USA–Nuclear-Power-Policy/

WNA. (2014c). *World nuclear power reactors & uranium requirements.* World Nuclear Association. http://www.world-nuclear.org/info/Facts-and-Figures/World-Nuclear-Power-Reactors-and-Uranium-Requirements/

WNN. (2010). *South Korea seeks to boost reactor exports.* World Nuclear News. January 13, 2010

Young, M. D. (1996). Cognitive mapping meets semantic networks. *The Journal of Conflict Resolution, 40*(3), 395–414.