Vol. 12: 81–97, 2012
doi: 10.3354/esep00125

ETHICS IN SCIENCE AND ENVIRONMENTAL POLITICS
Ethics Sci Environ Polit

Published online June 8

Contribution to the Theme Section: 'Ethical imperatives of dialogue for public engagement in technoscience'

OPEN ACCESS

EMF controversy in Chigu, Taiwan: contested declarations of risk and scientific knowledge have implications for risk governance

Shu-Fen Kao*

Graduate Institute of Asset Management and Urban Planning, University of Kang-Ning, Tainan, 70970, Taiwan, ROC

ABSTRACT: This article examines the controversy concerning the emission of electromagnetic waves at a meteorological radar site in Chigu, Taiwan, as an example of an emerging technological risk. At the heart of this controversy is a lack of scientific evidence and consensus regarding potential or future effects of the radiation on human health. The Chigu meteorological radar site started operating in 2000, and medical problems have inexplicably increased in one offshore community adjacent to this radar station since 2006. The community residents have long suspected that such disproportionate medical problems are a result of their daily exposure to electromagnetic waves from this meteorological radar site and now they are calling for this station to be dismantled. The Central Weather Bureau has responded to local residents' protests by claiming that no scientific evidence of such risk exists, according to the criteria set by the Environmental Protection Administration (EPA) in Taiwan and several documents published by the World Health Organization. Environmental activists and local residents have never agreed with such responses and claims. Controversies between both camps continue to fester. Drawing from arguments presented in studies by Funtowicz and Ravetz and the literature on participatory risk governance, the present study employs a qualitative approach, with in-depth interviews and analysis of documentary data, to investigate this case. The research delineates conflicting portrayals and framings of scientific knowledge and risk by technocrats and by civil society. The 'post-normal science' call for democratizing expertise has a critical role in providing a perspective through which a contemporary complex scientific controversy may be better understood in social-political contexts in Taiwan and shed light on better risk governance.

KEY WORDS: Declaration of risk · Scientific knowledge · Post-normal science · Electromagnetic field · EMF · Participatory risk governance · Deliberation · Meteorological radar · Taiwan

INTRODUCTION

There has been increasing public discussion regarding political decision-making processes in the development of science and technology. This trend is especially shown in the field of human health risk and environmental governance (Rowe & Frewer 2000). The traditional mode of a technology-related decision-making process, which is a 'top down' or 'rational–bureaucratic' model, has been questioned in Western society. For example, the US National Research Council has emphasized that decision-making tools regarding risk must be clearly reconceived, and the alternative model of a 'deliberative analysis process' would increase the possibility of reaching a decision that is acceptable and weighted (Stern & Fineberg 1996). With the rapid development of new technologies nowadays, Taiwan still lacks a competent risk-governance strategy, which has particularly been shown in the controversy about the human health effects of electromagnetic wave exposure.

*Email: kaosf@mail.ukn.edu.tw

Taiwan, located on the west side of the Pacific Rim, has a climate that shows characteristics of variability, making the use of meteorological radars necessary in order to collect data in a timely manner to provide better weather forecasts. Meteorological radar, also called weather surveillance radar and Doppler weather radar, is a type of radar used to locate precipitation, calculate its motion, and estimate its type (e.g. rain, snow or hail); it plays a critical role in providing precise weather forecasts in Taiwan, especially in the typhoon season. Meteorological radar sends directional pulses of microwave radiation, on the order of a microsecond long, using a cavity magnetron or klystron tube connected by a waveguide to a parabolic antenna. The wavelengths of 1 to 10 cm are approximately 10 times the diameter of the droplets or ice particles of interest, because Rayleigh scattering occurs at these frequencies. This means that part of the energy of each pulse will bounce off these small particles, back in the direction of the radar station (Doviak & Zrnic 1993). A radar beam spreads out as it moves away from the radar station, covering an increasingly large volume; therefore, the more emission power the weather radar has, the larger area it can cover for better weather forecasts. Although weather radar serves a critical role in collecting meteorological information, society now has some growing concerns about emission of its non-ionizing electromagnetic radiation leading to 'thermal effects' or side-effects of 'non-thermal effects'. The thermal effects (damage) can be best understood as biological effects of dielectric heating caused by electromagnetic fields (EMF). For example, standing around an antenna while a high-power transmitter is in operation can cause severe burns. This heating effect varies with the power and the frequency of the electromagnetic energy. A measure of the heating effect is the specific absorption rate (SAR) and many national governments have established safety limits for exposure to various frequencies of electromagnetic energy based on SAR, mainly based on the International Commission on Non-Ionizing Radiation Protection (ICNIRP) guidelines, which guard against thermal damage. Weaker non-thermal electromagnetic fields, including extremely low frequency magnetic fields and modulated radio frequencies (RF) and microwave fields, may induce changes in the protoplasm of blood, body fluids, lymph and cells, which may damage DNA within the cell, leading to gene and chromosome mutations and deformities. However, fundamental mechanisms of the interaction between biological materials and electromagnetic fields at non-thermal levels are not fully understood. How should the potential risks of meteorological radar in regard to human health be evaluated? The controversy concerning electromagnetic field (EMF) meteorological radar has never been a question of pure science, as it focuses more on the uncertainty and complicated interactions of technical-social systems, including health, ethical, economic, and social concerns. In other words, the emission of EMF from meteorological radar can no longer be viewed from a purely scientific or traditionally scientific viewpoint. It requires a new perspective to take a closer look at the problems and contentious issues involved in the EMF controversies in order to come up with a possible resolution for the current challenges we are facing. In this context, the theory of 'post-normal science' (Ravetz 1971, Funtowicz & Ravetz 1990, 1991, 1992, 1993) illustrates the contemporary nature of highly complex and ambiguous, highly conflicting values and the consequences of a high degree of scientific uncertainty. Post-normal science is characterized by uncertainty of the facts, the dispute of value, high stakes, and decisions that need to be made fairly urgently (Funtowicz & Ravetz 1992, p. 254). In terms of emerging high-tech products such as meteorological radar and its EMF, people may have to explore different risks and rethink the scope and areas of the safety assessment (Funtowicz & Ravetz 1992), and post-normal science theory may point towards a new model of participatory risk governance, which emphasizes the participation of civil society and varied stakeholders in decision-making processes to achieve risk management that seeks to reduce risk exposure and vulnerability by filling the gaps in risk policy (IRGC 2005, Renn 2008).

The present paper examines such a case regarding the health effects of EMF and the environmental controversy surrounding Chigu Meteorological Radar Station in southern Taiwan. The conflicting portrayals and framings of scientific knowledge and risks by governmental agencies, technocrats[1], and civil society will be delineated. The contested declarations of risks and scientific knowledge in this case illustrate that the high potential for complex interactions (Perrow 1994) and the highly uncertain scientific context in which these socio-technical systems operate results in a situation in which the management of potential risk becomes not only a technical and scientific issue, but also a social management task (Klinke & Renn 2001, 2002, Hom et al. 2009). Analysis

[1]Here, 'technocrats' refers to regulators and/or scientists appointed by the governmental science board.

of this case also offers fundamentally empirical evidence for the post-normal science call for democratizing expertise (Funtowicz & Ravetz 1990, p. 60–65 and p. 210), which serves as an antidote to a fairytale ideal of a clean divide between science and politics (Farrell 2011, p. 334), as well as providing us an opportunity to discuss issues of participatory risk governance of technoscience (IRGC 2005, Renn 2008, Renn & Schweizer 2009).

In addressing these aims, I will firstly review the early works of Funtowicz & Ravetz and other related literature as well as various theoretical perspectives on participatory/inclusive risk governance (e.g. Stern & Fineberg 1996, Tuler & Webler 1999, Renn 2004, Renn & Schweizer 2009). Then the literature on EMF and its health effects will be briefly reviewed. After that, methods and processes of data collection and data analysis are presented, followed by the context and history of the EMF controversy surrounding this meteorological radar technology in Taiwan, which not only sets the scene for further analysis in the section 'Contested declarations of risks and scientific knowledge', but also contains data based on an analysis of secondary documents, in-depth interviews with key actors, and participatory observations in the field. I will further analyze how risk and scientific knowledge are constructed by different social actors. Then, the implications for risk governance from this case study are discussed, followed by conclusions in the final section.

POST-NORMAL SCIENCE AND EXTENDED PEER REVIEW COMMUNITY

Characteristics of post-normal science

'Post-normal science' as a response to the concept of 'normal science' introduced by Kuhn (1962) has drawn much attention in research on scientific, political, and social management of risks in recent years. Normal science is 'research firmly based upon one or more past scientific achievements, achievements that some particular scientific community acknowledges for a time as supplying the foundation for its future practice' (Kuhn 1962, p. 10). In this traditional approach, science is viewed as a process in which the rules of science are debated and, through this process, scientific knowledge periodically undergoes paradigm shifts. When the previous beliefs, theories, and methodologies of normal science cannot resolve issues without conflict, it leads to revolutionary science. Existing rules of normal science are challenged and replaced by a new paradigm that is able to resolve some emerging contradictions. Ravetz (1971) criticized such views on revolutionary paradigm changes and denounced the industrialization of science, which was fortified by fighting for funding and grants, and where the quality of academic writing was subservient to the attainment of funding and personal promotion, which Ravetz (1971) termed 'shoddy science' (see also Diesing 1982). Ravetz called for the deindustrialization of science, which resulted in the idea of science as well as concerns and observations about its socially negative impacts all coming under scrutiny.

In responding to the need for new epistemic approaches beyond traditional science that could address issues characterized by uncertain facts, disputed values, high stakes, and urgent political decisions (Ravetz 1986), Funtowicz & Ravetz (1991) proposed post-normal science as a new mode of methodology, particularly for responding to controversies surrounding problems of normal science and the conventional peer-review process. Three factors interactively shape these problems together: uncertainty in the knowledge base, different framings of the problems, and inadequacy of the institutional arrangements at the science-policy interface (van der Sluijs et al. 2005, p. 481). Farrell (2011, p. 339–340) elaborated these conditions outlined by van der Sluijs et al. (2005): (1) conventional peer-review methods are ill-equipped for conducting quality checks on descriptions of some types of late-industrial scientific problems; (2) in these situations, technical matters are reviewed by an extended community of adjudicating peers, and quality checks on scientific output concerning these kinds of problems acquire an inherently political (value criteria) hue; and (3) this means that quality control on such scientific output needs to draw on combined judgments about both the social value and the technical adequacy of the science in question (Ravetz 1971), and there is a rationale for extended peer review, combining technical and political judgment, thereby democratizing expertise (Lee 1993). A 'risk management escalator' as coined by Renn (IRGC 2005, Renn 2008) also emphasizes a similar rationale for including diverse groups of stakeholders in the risk management process as uncertainty and ambivalence of the risk knowledge increase in order to reduce risk exposure and vulnerability.

Ravetz (1971, p. 157–162) distinguished between adequacy criteria and value criteria in the assessment of scientific knowledge production — the question of adequacy criteria (i.e. is it right?) can be placed within rule structures of 'normal' science but the question of value criteria (i.e. what should we study?) must be determined by society. Such a distinction, particularly with respect to the principle of peer review, reflects a presumption of fact/value disambiguity (Farrell 2011, p. 340). As Ravetz (1971, p. 159) stated, 'philosophical questions of the possibility and nature of scientific knowledge' are judged through reference to 'criteria of adequacy'; while 'criteria of value', which are related to 'the social activity of science', are used to adjudicate 'the choice of problems to be investigated'.

Scientific peer review, under 'normal' conditions, can be viewed as the application of adequacy-oriented quality control criteria, and science policy debates, such as setting research agendas, can be viewed as value-oriented quality control (Ravetz 1971). Therefore, an attribute of post-normal science problems — the intrusion of value-oriented social issues into the technical domain of science proper — can be viewed as undermining the presumption that a conventional peer-review process is sufficient for judging the technical quality of scientific work. Under post-normal science conditions, adequacy criteria and value criteria domains are no longer clear cut. The decision of whether a given technology should be developed is contingent upon the assessment of highly scientific and technical data concerning its functionality and associated risks. In another words, when high epistemological uncertainty is involved, adequacy data and value criteria fold in upon each other (Funtowicz & Ravetz 1993), and the basic criteria for judging the quality of a piece of scientific work change (Funtowicz & Ravetz 1985, p. 201; Farrell 2011, p. 342).

Extended peer review community

The concept of an 'extended peer review community' can be traced back to the early work of Ravetz (1971). In his description of 'facts and their evolution', an unequivocal description of extended facts and of the extended communities of individuals responsible for the evolution and reification of those facts are relevant to problems in other fields of enquiry (Ravetz 1971, p. 199). As he further argued that scientific knowledge's 'special character results from the complexity and interconnectedness of its materials [scientific facts], as they evolve through the complex and fallible social process of their use and adaption' (Ravetz 1971, p. 209), it is reasonable to propose that what is 'extended' under extended peer review is the role of the community of individuals to describe and decide what does or does not constitute a scientific 'fact'. In other words, the community of individuals who have internal authority to evaluate a piece of scientific work according to criteria of adequacy now is extended to include individuals who are responsible for making external quality judgments according to criteria of value. Ravetz (1971) also described a type of extended peer review community and peer-review process, which is somewhat more consistent with ideas discussed today under that term. Ravetz (1971, p. 44) argued that under the conditions of industrialized scientific knowledge production, scientists must first apply to the institutions or agencies that distribute funds in order to conduct any research; only if one of the funders considers the research project worthy of investment can this scientist proceed. This trend and procedures for deciding which scientific research project is worth conducting are without a doubt now influencing how research is carried out. Under such situations, the funder specifications become a key factor determining how a research project will be organized and executed, and quality controls based on value criteria intrude into the technical domain associated with adequacy judgments, stipulating not only what should be studied but also how it should be studied (Farrell 2011, p. 344).

On the flip side of the coin, the discussion of quality, such as the completeness of information, assessed by a wide range of epistemological and ontological positions, has been central to post-normal science. The quality control function of an 'extended peer community' does not have to operate based on conventional science criteria, but can serve to assess the quality of policy proposals on the basis of the community's own knowledge, which includes cultural and ethical perspectives (O'Connor 1999). As society now must cope with changes of all kinds that occur with increasing complexity, rapidity, and intensity; scientists themselves no longer believe that scientific objectivity can provide all that is needed for decision-making on risk issues (Jasanoff 1997). As an 'extended peer review community', those who are affected by or who have specific knowledge of the issue should be engaged to interact, discuss, and contribute their 'extended facts', such as local knowledge and conditions that traditional experts may not have (Rosa 1998), in order to facilitate the transmission of skills and quality of assurance of the results (Turnpenny et al. 2011, p. 292).

THEORETICAL PERSPECTIVES ON PARTICIPATORY/INCLUSIVE RISK GOVERNANCE

The increase in disputes and conflicts regarding siting a hazardous facility, setting standards for toxic chemicals, and/or regulating risks involved in the development of new technologies reveals that governments and/or corporations today are confronted with the increasing expectations of a society aware of the social and environmental impacts and risks associated with economic development and demanding more equitable distribution and deliberative management and governance of such risks to human health and the environment. It is now recognized that this needs to be done on the basis of a precautionary focus, acknowledging both the limitations of scientific prognosis and the complexity of the socio-technical systems under scrutiny. The implementation of the precautionary principle as a new critical element in the risk governance of potentialities in contemporary society requires a new conceptual framework (Klinke & Renn 2001, 2002). It is necessary to recreate the role of science, politics, and law in the context of more proactive protection and managing complex technological risks, in order to be more participatory and transparent in the use of information (O'Riordan & Cameron 1994). This new approach of risk governance, namely participatory or inclusive risk governance, highlights the participation of civil society along with other major actors like governments, the economic sector, and scientific communities to contribute all respective knowledge and the variability of values necessary to make effective, efficient, fair, and morally acceptable decisions about risks (Tuler & Webler 1995, Webler 1995, IRGC 2005, Renn & Schweizer 2009).

Renn & Schweizer (2009) addressed the conceptual issues of how to integrate the contributions of various groups of actors in risk governance, and indicated 6 underlying concepts of deliberation of citizen participation in risk governance in democratic societies, namely: a functionalist approach, neo-liberal approach, deliberative approach, anthropological approach, emancipatory approach, and a post-modern approach. The functionalist perspective aims to improve the quality of decision output through citizen participation to meet complex functions of society that need input of knowledge and values from various constituencies. Functionalist decision-making is oriented towards goal achievement and synthesizing knowledge and values with respect to a pre-defined goal (Renn & Schweizer 2009, p. 177). In the neo-liberal approach, deliberation occurs by setting a process to find one or more decision options that would optimize the payoffs to each participating stakeholder and help to find either one of the two solutions and provide acceptable trade-offs between overprotection and underprotection with respect to human health and the environment. Under these conditions, citizen participation must generate a representation of all values and preferences in proportion to their share in the affected population (Renn & Schweizer 2009, p. 177–178). In the deliberative approach, all relevant arguments should be included in the deliberation regardless of the proportion of their representation within the population, and through debate the criteria of truth, normative validity, and truthfulness are reached (Renn & Schweizer 2009, p. 178). The anthropological approach includes non-interested laypersons representing various social categories, such as gender, income, and locality, and highlights the independence of the jury, which means participants must be disinterested in the topic and engage in common sense as the ultimate arbiter in disputes (Renn & Schweizer 2009, p. 179–180). The basic ideas of the emancipatory approach are derived from Marxist or neo-Marxist social theories (Ethridge 1987, Jaeger at al. 2001) and its goal for inclusion is to ensure that the less-privileged groups of society are provided opportunities to speak and are empowered through their participation (Renn & Schweizer 2009, p. 179). The post-modern approach of public participation is based on Michel Foucault's theory of discourse analysis. It aims to reveal variability, plurality, and the legitimacy of dissent through acknowledgment of plural rationalities, thus demonstrating the relativity of knowledge and values (Fischer 2006, p. 25; Renn & Schweizer 2009, p. 179–180).

The model of analytic-deliberative decision-making (Renn 2004, IRGC 2005) deriving from combining the functionalist and deliberative approaches is also advocated by Stern & Fineberg (1996) and was reconfirmed by the US Academy of Sciences. Along with many similar methods (Durant 1999, Tuler & Webler 1999, Webler et al. 2001), this combined approach reflects one of the promising schemes for developing an integrated approach to participatory/inclusive risk governance based on inclusion of experts, stakeholders, and the general public (Stern & Fineberg 1996, Tuler & Webler 1999, Webler et al. 2001, Renn 2004, IRGC 2005, Renn & Schweizer 2009).

This combined approach utilizes systematic, rigorous, and replicable methods of formulating and evaluating knowledge claims, normally produced by scientists from various disciplines, such as natural, engineering, and social sciences as well as the humanities. Relevant knowledge often comes from stakeholders or members of the affected public (Horlick-Jones et al. 2007). Deliberation underlines the nature of problem-solving through collective consideration of relevant issues (Stern & Fineberg 1996, p. 73). It synthesizes varied forms of argumentation and communication, such as exchanging observations and viewpoints, weighing and balancing argumentations, offering reflections and associations, as well as putting facts into context. The idea of deliberation entails equality among various actor groups, the need to justify and argue for all types of claims, and an orientation towards mutual understanding and learning (Tuler & Webler 1995, Webler 1995, 1999, IRGC 2005, Renn 2008, Renn & Schweizer 2009).

The strengths of this analytic-deliberative approach of participation are fourfold. First, it generates common understanding of the issues/problems based on the joint learning experience of the participants with regard to systematic and sketchy knowledge (Webler at al 1991) and it may produce mutual understanding of each group's position and argumentation, thus facilitating a mental reconstruction of each actor group's argumentation. Second, it creates new options for action and solutions to a problem. Through clarifying the problem, people become aware of framing effects and determine the limits of what could be called reasonable within the pluralist interpretation (Skillington 1997). Third, when all arguments are exchanged, opposite participants not only would understand why they disagree but would eventually understand the reasons why their opponents came to their conclusion. Once these options have been subjected to public debate, governmental agencies or parliaments could make the final decision in accordance with legitimate rules and institutional arrangements. In addition, deliberation creates 'second order' effects on individuals and society by providing insights into the fabric of political processes and creating confidence in one's own agency to become an active participant in the political arena. Finally, deliberation may possibly, but this is not a mandatory requirement, result in consensus that serves the 'common good' best without being at the expense of some interest violations or additional costs to certain groups (Renn & Schweizer 2009, p. 182).

The literature above provides us with an ideal blueprint for deliberation in risk governance; however, in reality, conflicts about the best structure of a participatory process often emerge from overt or latent adherence to one or another approach. All approaches regarding deliberation to include citizen participation in risk assessment and management can be found in different formats and combinations within the field of environmental policy making and risk governance in different countries. What is the outlook of citizens' participation in the field of risk governance of EMF in Taiwan, particularly in the controversy surrounding the case of the meteorological radar? Is there any analytic-deliberation interaction going on in this case? Or is it simply an ongoing struggle between 'scientific facts' and 'public emotions'? What does this case study tell us about risk governance of EMF and weather radar technology in Taiwan? After briefly reviewing the literature on EMF and its health effects, and delineating the methodology I used for the case study, I will provide an analysis to answer these questions.

EMF AND ITS HEALTH EFFECTS

EMF is a physical field produced by moving electrically charged objects. The field can be viewed as the combination of an electric field produced by stationary charges and a magnetic field produced by a moving charge (currents) (see http://en.wikipedia.org/wiki/Electromagnetic_field). During the 20th century, environmental exposure to human-made EMFs has been steadily increasing, as growing electricity demands, ever-advancing technologies, and changes in social behavior have created numerous artificial sources of EMF.

Over the past decade, numerous sources of EMF have become the focus of health concerns, including power lines, microwave ovens, computers, security devices, radar, and mostly recently, mobile phones and their base stations. The potential effects of EMFs on human health vary widely, depending on the frequency and intensity of the fields. In response to growing public health concerns over possible health effects from exposure to an ever-increasing number and diversity of EMF sources, the World Health Organization (WHO) launched the International EMF Project (see www.who.int/peh-emf/project/en/). This project brings together the current knowledge and available resources of key international and national agencies and scientific institutions. In addition, approximately 25 000 articles have been published over the past 30 yr about the biological effects and medical applications of non-ionizing radiation. Based on a recent review of the scientific literature, the WHO concluded that the current evidence does not confirm the existence of any health consequences from exposure to low-level EMFs. However, some gaps in the knowledge about biological effects exist and further research is required (see www.who.int/peh-emf/about/WhatisEMF/en/index1.html). The potential health effects of very low-frequency EMFs surrounding power lines and electric devices are the subject of ongoing research and a significant amount of public debate.

People who live or routinely work around radar may have concerns about the long-term adverse effects of EMFs on their health, such as cancer, reproductive malfunction, cataracts, and changes in behavior or development of children. An example has been the alleged increase in testicular cancer among police officers using hand-held radar speed-control 'guns' (Lotz et al. 1995). In addition, many epidemiological studies have also addressed possible links between exposure to RF and an excessive risk of cancer. However, because of differences in the design and execution of these studies, the results are difficult to interpret. Although the WHO has concluded that there is no convincing scientific evidence that exposure to RF shortens the lifespan of humans, or that RF is an inducer or promoter of cancer, the WHO also stresses that further studies are necessary (WHO 1999). Epidemiological data on possible health effects of chronic, low-level, whole-body exposure in the far-field of RF transmitters are poor, especially because of lack of satisfactory individual exposure assessment (ICNIRP 2009).

As for international standards, according to ICNIRP guidelines, environmental RF levels from radar, in areas normally accessible to the general public, are at least 1000 times below the limits for continuous public exposure, and 25 000 times below the level at which RF exposure has been established to cause the earliest known health effects (WHO 1999). As for protective measures, the WHO emphasizes that the aim is to eliminate or reduce human exposure to RF fields below acceptable limits. An extensive program of measurement surveys and hazard communication, coupled with effective protective measures, is required around all radar installations. In most countries, comprehensive documentation is prepared, including an environmental impact statement, before a radar system can be constructed (WHO 1999).

METHODOLOGY

The goals of the present study were to analyze the contested declarations of risks and scientific knowledge surrounding EMF issues of meteorological radar in southern Taiwan between 1998 and 2011, and utilize the findings to further discuss the implications for risk governance. This study is a part of the research project 'Risk of new technology, environmental controversy and risk governance – applying "Consensus Conference" as a model of risk governance for EMF controversy of weather radar in Chigu' funded by the National Science Council in Taiwan. All aspects of this study received approval from the National Science Council in Taiwan. I employed a qualitative approach that drew upon in-depth interviews, analysis of documentary data, including newspaper accounts, petition documents, reports of public hearings, newsletters of The Taiwan Electromagnetic Radiation Hazard Protection and Control Association (TEPCA), and information provided on the websites of the Environmental Protection Administration (EPA), Central Bureau of Meteorology, TEPCA, WHO, ICNIRP, etc., as well as field observations, to understand this specific case in Taiwan.

From early 2010 to October 2011, I conducted 25 in-depth interviews with informants from 5 major groups: (1) community residents in Yancheng Village in Chigu, Taiwan; (2) governmental officials from the EPA, the Central Bureau of Meteorology, and the Southern District of Meteorological Center; (3) environmental activists from TEPCA; (4) scientists and scholars in the fields of public health and radiobiology; and (5) medical doctors. In addition, I observed social advocacy in various settings, such as local protests, meetings in the community, a nation-wide rally in Taipei, and a public hearing and meetings among stakeholders in Legislative Yuan.[2]

I employed the approach of template analysis (Crabtree & Miller 1992) to analyze the various qualitative data collected. Template analysis is often referred to by other terms such as 'codebook analysis' or 'thematic coding'. The essence of the approach

[2]The Legislative Yuan in Taiwan has the power to decide by resolution upon statutory or budgetary (final accounts) bills, or bills concerning martial law, amnesties, declarations of war or peace, treaties, and other important affairs of the state. Any law, statute, special act, or general principle has to be passed by the Legislative Yuan and promulgated by the State President before it comes into force. Executive decrees issued by any central government agency must be submitted to the Legislative Yuan to be either taken note of or be referred to a committee for examination. Should the Yuan determine that a decree contravenes, alters, or violates any law, or that a decree has regulated certain matters that should have been stipulated by law, the Legislative Yuan may, upon the resolution of the Yuan Sitting, inform and request the initiating government agency to revise or revoke the decree within 2 mo. Should the said governmental agency fail to do so, the decree is voided forthwith.

is that the researcher produces a list of codes (a 'template') consisting of a number of categories or themes relevant to the research questions (King 1994). Template techniques vary in the extent to which the codebook is built upon existing literature and content of the research question (*a priori*) or is developed from initial analysis of the textual data (*a posteriori*). In both cases, however, the codebook is modified and added to as the researcher reads and interprets the texts (King 1998). In the present study, I used the existing literature, interview question guides, my field notes, and initial analysis of my interview data to construct an initial template for studying the weather radar EMF controversy incident in Taiwan. Then, I revised the template by reading systematically through the full set of transcriptions and textual data a number of times, identifying sections of texts which were relevant to the research aims, and making them into one or more appropriate codes from the initial template. The final version of the template was constructed through the following procedures: repeated reading of the textual data, inserting new codes for inclusion in the text relevant to the research question but not covered by an existing code, deleting codes which were found to overlap substantially with other codes as a result of redefinition or its lack of relevance to the study, changing the scope of the code by redefining it at a lower or higher level, and changing the higher-order classification. Finally, by identifying the emerging themes and drawing illustrative examples from each transcript or other texts, an account of the findings of this study was developed. The following sections present these findings.

HISTORY OF THE EMF CONTROVERSY IN CHIGU, TAIWAN (1998–2011)

From unawareness of the existence of electromagnetic waves to realization (1998–2005)

In November 1998, the Bureau of Meteorology in Taiwan selected Yancheng Village in Chigu, Tainan as a Doppler meteorological radar site without notifying local residents. In December 2000, the Chigu Meteorological Radar Station[3] started operating, collecting hydrological and meteorological data in the atmosphere of the western region of Taiwan. On 12 January 2001, the EPA in Taiwan announced the recommended criteria for general public exposure to EMF: 833 mG for low-frequency EMF (such as electric appliances in the household); for RF EMF, 0.45 mW cm^{-2} for 900 MHz and 0.90 mW cm^{-2} for 1800 MHz (see http://ivy1.epa.gov.tw/nonionized_net/EMF/safety.aspx [accessed 2 December 2011]). Due to the concerns of local residents regarding their daily exposure to EMF, the Chigu radar center set up the first official detection system for electromagnetic radiation on 19 September 2003. This system was implemented by the EPA, and the detection results were found to be in compliance with the criteria set by the EPA in Taiwan. However, local residents doubted the accuracy of these results and questioned the legitimacy of such detection, since the detection tools, detection procedures, and detection content were all determined by a governmental agency (EPA) without external cross-examination or independent witnesses. Since 2005, the controversy over EMF emissions and negative effects on health has received social attention, as local protests against EMF exposures have manifested throughout Taiwan (see news item dated 8 May 2010 at http://news.epochtimes.com.tw/10/5/8/138234.htm). In October 2005, a professor from Tainan trained in the field of radiobiology and who personally suffers from 'electromagnetic hypersensitivity' began to campaign for tighter control of electromagnetic radiation in Taiwan (from my interview with her on 16 November 2010). Drawing from her personal experiences, the professor has visited communities encountering risks from EMF and investigated EMF exposures of local residents, including Yancheng village. Not only has she collected electromagnetic protection standards from other countries, but she has also introduced such information to local communities and facilitated the formation of local protest groups.

From social perceptions of risks to initiation of collective action (2006–2007)

In mid-2006, one local resident in Yancheng who used to repair radar in the airforce and later became the leader of a local protest group discovered several medical cases, such as cancers, hearing impairments, and strokes, that had occurred in his village (from my interview with him on 8 March 2010). In addition, some of the workers in a fishery field near the radar

[3]This Chigu meteorological radar, launched in the year 2000, is 1 of 4 weather radar stations in Taiwan. The other 3 meteorological radar sites were set up in the mountains or sparsely populated areas, in which no housing occurs within a radius of 150 m from weather radar. This Chigu weather radar station, as the only exception, is located near Yancheng Village, in southern Taiwan.

station inexplicably passed away. One household, adjacent to the weather radar station, had 3 children who were diagnosed with mental development issues and problems. The community residents have long suspected that such disproportional medical problems in this community are a direct result of their daily exposure to electromagnetic waves from the weather radar since 2000. Many in the community are now calling for the government to dismantle this weather radar station. On 13 October 2006, the Southern District Meteorological Center commissioned the Qingling Industrial Development Foundation at National Taiwan University and the Center of Measurement in Industrial Research Institute to conduct a second detection of EMF exposures. The 2 agencies concluded that more evidence and further scientific research was required in order to determine if the radar station indeed posed a threat to local residents.

Since 30 November 2006, local residents have been petitioning both the local and central governments. On 26 June 2007, the Southern District Meteorological Centre responded to these petitions by holding a meeting with local residents, a majority of whom were elderly. Biased promotional-like descriptions of the regulatory criteria and safety of EMF, filled with scientific jargon, were presented to the community residents (from my interviews with the residents on 12 and 18 January 2011). This response from the government did not help local people to understand EMF issues, nor did it allay their fears and anxieties. On the contrary, the government's response seemed to strengthen local residents' opposition to the weather radar station. The next day, a local protest group comprised of about 50 villagers carried a protest banner entitled 'Radar Station, Get Out!' and protested outside the office of the Southern District Meteorological Center (from my interviews with the residents on 12 and 18 January 2011). Protesting residents and police became involved in a violent confrontation that resulted in severe injuries (from my interviews with the residents on 18 January 2011).

Expanding organized collective resistance through discourse-making in the legislative system (2007–2011)

In late 2007, local residents, with the help of TEPCA, expanded their collective resistance from actions of protest to the use of discourse in the legislation system. Not only did they appeal to City Councillors and Members of Congress to draw attention to this case, but they also signed petitions and appealed to the government, hoping to generate political pressure. On 23 November 2007, various groups, including government officials from the Department of Transportation, the Southern Weather Bureau, the EPA, and the Department of Health, as well as local residents, and several representatives from environmental non-governmental organizations (NGOs), were brought together for a public hearing before the Legislative Yuan (from my interviews with leaders of the local protest group on 5 and 7 January 2010).

In this public hearing, governmental agencies indicated that electromagnetic radiation levels in the local community were all below the 'suggested safety level' in accordance with international standards. Thus, they were not in favor of relocating the Chigu Meteorological Radar Station (from my interview with an official from the Southern District Meteorological Center on 10 January 2011; this data was also documented in the report of this public hearing among various stakeholders in this case). Local residents stressed the fact that since the station began operating in 2001, a great discrepancy began to emerge between governmental statistics and the number of local deaths and disabilities. Local residents further pointed out that the meteorological radar began to operate in 2001, so it was a fallacy for the government to utilize data from 1996–2001 to contrast data from 2002–2007. In addition, local residents emphasized that the impact of electromagnetic waves on human health is a long-term rather than a short-term pathogenic phenomenon (from my interviews with leaders of the local protest group on 5 and 7 January 2010). Representatives from environmental NGOs said that they are highly concerned about the harmful effects of electromagnetic radiation upon human health, stating that in addition to increasing negative psychological impacts, the longer the period of EMF exposure, the worse the negative effects on human health. They concluded that because of current scientific uncertainty on safety standards for long-term exposure to EMF, it would be better to relocate this meteorological radar site (from the Report of the Public Hearing on 23 November 2007). After hearing various perspectives from the different actor groups, the chairperson of this conference suggested that the government should be sympathetic to the local residents' concerns. He further indicated that the Chigu Meteorological Radar Station was very close to a residential area and local residents' consents were not obtained when it was established. Thus, he suggested that the government should relocate this radar station. In the end, while a consensus was not reached, different viewpoints regarding EMF health risks surrounding this meteorological radar site were at least heard by various actor groups at this public hearing, which seemed to be the very first step in communication among these groups.

On 22 February 2008, a former airforce officer, who had 28 yr of experience in repairing radar, began to become more actively involved in this issue after he heard about this case. Based on his knowledge of radar and his experiences in repairing radar, he believed that the radar beam was being reflected to the ground, which resulted in the various health problems that were occurring among local residents. He provided knowledge about EMF to local people, which has gradually shaped their knowledge and understanding about EMF. On 14 March 2008, this former airforce officer worked with the leader of a local protest group in addressing petitions and submitting them to the Control Yuan[4], Executive Yuan, EPA, Department of Health, National Communications Commission (NCC), Department of Transportation, Central Weather Bureau, Bureau of Health in the Department of Health, Taiwan Power Corporation, and other governmental agencies. In these petitions, information and knowledge regarding EMF and radar electromagnetic wave emission paths were clearly stated along with illustrations. In particular, it was indicated that beams of radar with a MW pulse were like a bullet firing, so the impact of a radar pulse is far more than RF low-power continuous waves from base stations, which is why ground safety issues have been specifically regulated internationally (from my interview with the former airforce officer, who had 28 yr of experience in repairing radars, on 12 January 2011).

This former airforce officer believed that ground safety was already violated, as the meteorological radar was constructed 100 m away from Yancheng village. Official replies from various governmental agencies each contained a typical response — the standards were based on recommended criteria for short-term exposure, and previous EMF detections conducted on site all met the criteria set by the EPA in Taiwan, which was in line with international standards, and moreover, the Department of Health will continually conduct risk communication briefings. These replies were unable to resolve the doubts and suspicions of the local villagers. On the contrary, they amplified local people's resentment and led to a greater degree of distrust. From this time on, contested risk discourses intensified.

[4]The Control Yuan in Taiwan, according to the Constitution and its additional articles, has the powers of impeachment, censure, and audit. It may also take corrective measures against governmental organizations.

CONTESTED DECLARATIONS OF RISKS AND SCIENTIFIC KNOWLEDGE

Here, contested declarations of risks and scientific knowledge of this EMF controversy will be elaborated in 3 subsections: the controversy surrounding the interpretation and translation of the scientific literature; conflicting perspectives about the natural background radiation level; and different viewpoints from various social actors regarding the application of the precautionary principle for prevention and control legislation to regulate electromagnetic safety.

Contested interpretation/translation of credible scientific literature

With reference to guidelines from the ICNIRP, the EPA in Taiwan announced a 'suggested criteria for exposure of the band value of non-ionizing radiation for the general population in the non-occupational setting' on 12 January 2001. The criteria are for 2 major categories: low-frequency and high-frequency EMF. The criterion for low-frequency exposure is 833 mG. For mobile phones and base station types of high-frequency EMF, the criteria are 0.45 mW cm^{-2} for 900 MHz, 0.9 mW cm^{-2} for 1800 MHz, and 1 mW cm^{-2} for meteorological radar stations of 2836 MHz. When the conflicts surrounding the health effects of EMF from the Chigu Meteorological Radar Station emerged, the Central Weather Bureau responded to local residents' protests by claiming that no scientific evidence of such risk exists, according to the safety standards of EMF exposure set by the EPA in Taiwan and several documents published by the WHO. However, local community and environmental groups refute the Central Weather Bureau's claims by citing international epidemiological studies such as the Bioinitiative Report and electromagnetic radiation safety standards promulgated in countries like Germany and Sweden. In addition to utilizing different sources of scientific literature, the use of different interpretations of the same scientific documents and varied Chinese translations of specific terms resulted in controversies between the 2 camps.

According to ICNIRP (2010) guidelines proposed in 'the basic restrictions': 'The main objective of this publication is to establish guidelines for *limiting EMF exposure* that will provide protection against adverse health effects. As noted above, the risks come from *transient* nervous system responses including peripheral (PNS) and central nerve stimulation (CNS), the induction of retinal phosphenes and possible effects on some aspects of brain function' (ICNIRP 2010, p. 825).

The chairperson of TEPCA emphasized that the restriction is to set a limit for possible harm from acute EMF exposure and strongly disagreed with the translation wording and criteria set by the EPA in Taiwan in 2001. In the Taiwan EPA's official document, the wording was 'suggested criteria for exposure of the band value of non-ionizing radiation for the general population in the non-occupational setting', which later was commonly termed by the government as 'environmental suggested criteria'. However, the TEPCA chairperson stressed that the limits set by EPA in Taiwan should be read as acute EMF exposure that results in thermal effects on the human body. Therefore, the criteria suggested are not criteria of safety. She repeatedly stressed this during my interview with her (21 August 2010):

> What are the original words of 'environmental suggested criteria'? It is a 'guideline for *limiting EMF exposure* that will provide protection against adverse health effects. As noted above, the risks come from *transient* nervous system responses from…'. The definition of the guideline has never been clearly delineated among scholars in Taiwan. Therefore, the Tai-Power Corporation, the NCC and the Telecommunication Corporations all indicate that it is safe below 833 mG. The National Health Council and the Bureau of Meteorology both stated that 1 mW cm^{-2} for the Chigu Meteorological Radar Station was safe, so there is no need to relocate the radar…[the] ICNIRP in the final section of 'Considerations regarding possible long-term effects' of its 2010 document did state: '…The absence of established causality means that this effect cannot be addressed in the basic restrictions. However, risk management advice, including considerations on precautionary measures has been given by the WHO…' The ICNIRP has not set a basic restriction for long-term effect because there is no established mechanism. Simply speaking, maybe there's a risk… In other words, they cannot set a limit

From my observation, there is a contrast of discourses between government and NGOs. Environmental groups say that 833 mG and 1 mW cm^{-2} refer to limits for 'thermal effects'. Regarding 'non-thermal effects', no causal relationship has been established at this point, so a basic restriction could not be made. However, it does not mean there is no evidence of risk. The technocrats consider that it is safe and no risk is involved if it is below 'environmental suggested criteria' set by the EPA in Taiwan. In other words, the government does not differentiate between 'thermal effects' and 'non-thermal effects' even using the same criteria for reference.

Conflicting perspectives about the natural background radiation level

Background electromagnetic radiation level is a reference value which helps us to understand the extent of EMF exposure in a specific environmental condition. Contrasting EMF exposures between 2 different environmental conditions assists in evaluating environmental risks, thereby giving meaning to the number of testing results. Environmental groups consider that most locations of background high-frequency electromagnetic waves from base stations, wireless Internet IP sharing devices, or meteorological radar stations should generally be only 0.1 mW m^{-2}, or even close to zero. They also propose that the value for long-term indoor electromagnetic wave exposure should not be high and must follow limits (set by e.g. Salzburg, Austria) of 1 μW m^{-2} for indoor high-frequency electromagnetic waves and 10 μW m^{-2} for outdoor waves, or follow the Building Biology Guidelines set by the German International Institute for Bau-Biologie and Ecology (IBE) in 2003, which sets the limit of EMF to <5 μW m^{-2} for indoors and sleeping environments.

Following ICNIRP standards, the limits of high-frequency electromagnetic waves were set by the EPA in Taiwan: the outdoor exposure standard value is 9 million mW m^{-2} for 1.8 GHz frequencies and 10 million mW m^{-2} for 2.0 GHz, which are much higher than the natural background levels. Environmental groups have disagreed with the claim made by the risk management agencies that it is safe if the values are below criteria set by the EPA. The environmental groups are concerned that such information from the EPA's regulation may be misleading to the public, which can result in no protective measures taken among the public and exposure of the general public to excessive electromagnetic radiation emission, especially since the population density in Taiwan is high. Environmental NGOs emphasize that the public often stay in indoor environments for a long time; therefore, the government and legislative agency should regulate the indoor natural background levels according to German IBE guidelines or standards proposed by the Bureau of Health in Salzburg.

Should the precautionary principle be adopted in protection measures?

The WHO and the International Agency for Research on Cancer (IARC) published a report in 2002 (IARC 2002) indicating that children exposed to extremely low frequency residential magnetic fields greater than 0.3 to 0.4 μT have a two-fold increase in the risk of childhood leukemia. Thus, extremely low frequency electromagnetic radiation is included within the category of 2B carcinogens, which refer to agents classified as possibly carcinogenic to humans. Examples are lead and DDT (4, 4'-Dichlorodiphenyltrichloroethane) (IARC 2012). In addition, the specific absorption rate (SAR) of electromagnetic radiation serves as an important measure of whether the risk affects human health. The SAR value, of the amount of radiation absorbed by the body, can be an indicator of thermal effects or non-thermal effects caused by electromagnetic radiation. The higher the SAR value is, the more effects the radiation has on the human body.

A professor from the field of public health indicated that cancer risk increases when people have been exposed to high doses of high frequency electromagnetic radiation, and even exposure to extremely low frequency electromagnetic radiation may result in cancer risk increase; however, related studies of non-thermal effects lack reproducibility (from my interview with a public health professor on 24 August 2010). In addition, mechanisms of effect and dose-effect relationships have not yet been clearly stated (Ahlbom et al. 2004). Therefore, 'non-thermal effects', in the current stage of the research and under the paradigm of traditional scientific research, still has not yet reached the so-called 'dangerous' threshold. However, it should not be defined as 'safe', either. As one professor from the field of law expressed, the issue of 'non-thermal effects' has a credible basis for establishing initial suspicion of current scientific theory, but it seems to lack sufficient positive evidence to prove that it is harmful. The argument can also be made that without sufficient evidence to support it being non-hazardous, the initial scientific suspicion can be completely excluded. Therefore, to sum up, 'non-thermal effects' of non-ionizing radiation on human health, at the current stage, is a phenomenon marked by uncertainty and chaos in Taiwan (from my interview with the law professor mentioned above on 27 February 2011).

Those who disagree with adopting precautionary principles into protective measures have the following rationales. First, under the presumption of the scientific uncertainty about EMF health effects, once the precautionary principle is adopted, it may result in societal hysteria and more unreasonable anxious concerns about EMF among citizens, which eventually leads to psychological damage. As one technocrat stated in his book (Lin 2008, p. 106):

> Precautionary principle has its side-effects. The issues of EMF safety require considerable amount of scientific and technological knowledge for correct understanding. Generally speaking, the public tend to be irrationally panicked about it. In order not to misuse the precautionary principle and let the whole society be at peace with electromagnetic waves, it really requires accurate reasoning and a good judgment from those who can judge well. Therefore, when the public has not been able to understand EMF issues well, the implementation of precautionary principle would be with more harmful than good effects

Disputes exist in discussions about the application of the precautionary principle and scientific uncertainty of EMF health effects. Some scholars believe that focusing on early warnings led to scientific inquiry being kidnapped by special interest groups (Charnley & Elliott 2002). Majone (2002, p. 107) also pointed out that policymakers sometimes abuse the precautionary principle by making unscientific or irrational decisions in order to cover up their bad decisions in the political realm.

Those who emphasize adopting the precautionary principle into protective measures present the following arguments. Although the effects of non-ionizing radiation upon human health and its potential environmental impacts may not be fully identified through current scientific knowledge, its indirect negative long-term or delayed effects are unknown and its specific biological effects could be irreversible. In addition, under the context of the current impossibility of quantifying the risks and lack of certain scientific knowledge, it is difficult to establish causal relationships in the traditional scientific sense. Even if the probability of risks is unknown, the negative impacts are known.

People from this camp point out that although electromagnetic radiation is invisible and without smell, it is likely to cause serious physical harm, and adopting the precautionary principle into protective measures should be the best preventive strategy. They further indicate that developed countries carefully set relevant regulatory constraints to prevent unnecessary exposure from electromagnetic radiation in the public's daily living environment. Such regulatory actions could protect people's lives as the last defensive mechanism in the face of misguided development. Moreover, they attribute a safe residential environment with low EMF exposure in developed countries to their implementation of precautionary principles. As one environmental leader who is also a university professor stated (when interviewed by me on 21 August 2010):

> In Europe, the average dose for residential extremely low-frequency electromagnetic field is about 0.7 mG and [it is] 1.1 mG for North America, according to the WHO N322 document. In addition, one WHO report indicated that [in] the United States, Japan, Germany, and Belgium … etc., about 90 % of residential indoor extremely low frequency electromagnetic fields are no more than 1 mG. Such a low dose of electromagnetic radiation in people's daily living environment is a result of the implementation of [the] precautionary principle, as [the] precautionary principle has become a trend and position for protective mechanisms adopted by many developed countries.

In the context of scientific uncertainty in regards to EMF health problems, currently there is no in-depth discussion concerning whether precautionary principles should be adopted and if so, under what conditions should they be adopted. Local communities that have faced EMF risks because of their proximity to facilities such as mobile-phone base stations, high-voltage power lines, or weather radar stations have increasing suspicions about potential harm from electromagnetic radiation emission from these facilities. There are also growing confrontations against the siting of these modern technological facilities. These phenomena in Taiwan all reveal an urgent need to examine the current systems of risk assessment/governance.

IMPLICATIONS FOR RISK GOVERNANCE

Findings in this case study reflect that when the government, from time to time, improperly manages risk events in various decision-making processes, the public's confidence in the government administration falls (Löfstedt 2003). Scholars (Beck 1999, Kasperson 1992) have pointed out that the public's risk perception is a complex, subjective, and social construction process, so the actions and responses of the government, media, and social movement groups to risk events is critical. In addition, Savadori et al. (2007) pointed out the importance of the communication of information, as the efficiency of information communication will affect people in their risk assessment and judgments. It is possible for people to lose their trust in the system if the government cannot manage risk and disputes effectively, such as failing to provide more scientific facts, simplifying the uncertainty and ambiguity of scientific findings in order to attenuate risk perceptions (Kao 2008), or considering the stakeholders, particularly the public or the impacted population, to be irrational/ignorant without engaging with them over the course of risk assessment and risk communication. In this case, not only was there no environmental impact assessment conducted, but the community residents were not informed before construction of the radar station commenced. Issues of procedural injustice (local stakeholders were not informed prior to the construction of this weather radar) and environmental injustice (this radar was constructed about 100 m away from the community; residents in this community possibly have sustained the cost emotionally and physically) have been raised in this meteorological radar EMF controversy. Unfortunately, the governmental agencies have responded to the suspicions and concerns of local residents about health effects with one-way promotional claims and an over-simplification of scientific facts. What has been communicated to the local residents is the claim that 'it is safe' once it is under the limits of exposure guidelines. In fact, documents from the WHO and the ICNIRP also emphasize that more scientific research in this field is necessary and various protective measures from exposure to EMF from radar are required, which has never been stressed in the course of risk communication by the governmental agencies.

Nowadays, technological complexity is often used as a main weapon to deal with 'NIMBYism' ('not in my backyard'). When policy decision-makers face various incidences of risk controversies, they often rush to carry out implementation of policies on the grounds of a high degree of complexity of environmental issues and/or lack of technology and resources to tackle problems. Conversely, under a certain amount of pressure and time limitations to make decisions, the technocrat, in order to reach a compromise, often combines scientific and political decision-making (Jasanoff 1990). The electromagnetic risk controversy surrounding the Chigu meteorological radar site in Taiwan may have been enhanced because the local community was not sufficiently included in further scientific inquiry and the decision-making process of risk governance. In fact, weather radar sites are normally situated in remote areas. Moreover, even if a weather radar is accessible to the public, it is very unlikely for the general public to be exposed to EMF on a daily basis. Therefore, a case like this, with long-term daily exposure to EMF caused by close proximity of weather radar to a residential area, is rare. When local residents began to raise concerns about health problems, it presented a good opportunity for risk regulators and/or risk management agencies as well as researchers to further investigate the health effects of exposure to daily long-term EMF. At the very least, protective measures should have been implemented. Sadly, risk management agencies in Taiwan failed in terms of competent risk management/governance in this case.

If we consider management style in relation to the post-normal science characterization of problem-solving strategies, we see that the case of the Chigu meteorological radar EMF controversy was managed largely by 'applied science', together with 'professional consultancy', and with very little touch of 'post-normal science' in the involvement of local communities in the early stage of the controversy. Although local community and environmental groups have challenged the legitimacy of risk assessments from the government and demanded clarifications of definitions of problems, and dialogues between counterparts (mobilizing resources in the legislation system) have taken place, these stakeholders' voices have only just begun to be heard: there is still a long way to go. The case of the Chigu meteorological radar EMF controversy provokes the question of whether the traditional Taiwanese system of governance is prepared enough for new types of risks. This EMF controversy over a meteorological radar station is embedded in the broader context of EMF risks that vary from mobile-phone base stations to high-voltage electric towers, which also involve uncertain health risks for local residents from long-term EMF exposure. In fact, the implications become more critical when societal concern for safety from EMFs emerges in the midst of epistemological uncertainty of scientific knowledge. This case provides empirical evidence of the characteristics of post-normal science: (1) the uncertainty of scientific knowledge concerning the disproportional health problems and their relationship with long-term daily exposure to EMF from weather radar; (2) whether precautionary principles should be implemented in this case (disputed values); (3) ongoing social advocacy from the local residents and the loss of their trust and faith in the government and risk management agencies (high stakes); and (4) a great need to restore social trust (urgent political decisions). However, in terms of analytic-deliberative interaction between the most impacted stakeholders and the risk management agencies, this case reveals a lack of deliberation by the government and its agencies in engaging citizens and local impacted stakeholders in risk assessment/governance up to this point. All the relevant governmental agencies, such as the EPA, Bureau of Health and the Bureau of Meteorology, have been challenged by local residents and environmental NGOs to examine the effectiveness of their risk governance.

Science can provide important information, but cannot determine correct policies. It is uncertainty which dictates and demands the reference to explicit values upon which good policies are based. On the one hand, these are realized in the assignment of the burden of proof, either 'precaution' or 'prudent no regrets', or on the other hand, 'proof-first' or 'safe until proved dangerous' (De Marchi & Ravetz 1999, p. 755). When local knowledge about risk is not taken into account or not properly respected, there may be serious consequences in terms of trust, which could threaten governance in general by a withdrawal of public trust in governmental scientific establishments. It is possible that in this EMF controversy, which originally undermined the local residents' trust in the government and technocrats, trust may be partially restored, with the resumption of normal life, if some precautionary actions and improvements in regulation are undertaken. However, if people continue to experience a constant lack of concern from government officials for apparently speculative hazards and feel that the government is unresponsive to people's anxious concerns, trust could begin to deteriorate.

One of the antidotes to this challenge is to move in the direction of having an 'extended peer review community' with some degree of legitimacy and influence. These are variously described as, for example, 'citizen juries', 'focus groups', 'consensus conferences', or 'stakeholder forums'. These must be included in risk governance systems and operate so as to encourage dialogue and foster mutual respect. When stakeholders are involved in a specific issue, either as laypersons or counter-experts, they are treated as potential peers, sharing the definition and management of a problem. Additionally, they can contribute resources of local knowledge and understanding that complement the generalized knowledge of scientists or technocrats. Concerned citizens have shown that they can handle uncertainty and disagreement among scientific experts quite well. What makes them upset is a sense of being patronized or of problems being concealed from them. Building trust is about behaving with integrity within the confines of one's role in a negotiation. The appreciation of those roles in risks can help all participants to 'see ourselves as others see us' (De Marchi & Ravetz 1999, p. 756), and then enhance a genuine dialogue. Ethical commitments cultivate naturally out of such dialogue as each side comes to appreciate the others' integrity and the legitimacy of their point of views (Susskind et al. 1995). Therefore, the mechanism and design of involving extended peer review communities into the implementation of a program for 'knowledge assessment' is vital, as cultivating mutual trust is central to this new model of participatory risk governance in relation to risks and environmental or health hazards.

CONCLUSIONS

With the rapid development of emerging technologies, competent risk management/governance is critical. I consider competent risk governance to include transparency of information, analytic-deliberative engagement of various stakeholders with different values and openness to new scientific findings. In terms of these aspects, Taiwan still lacks a competent risk management/governance strategy, which is manifested particularly in the controversy of human health effects from electromagnetic wave exposure. The public's risk perception was placed behind a wall of scientific uncertainty, and dissenting experts, who disagree with definitions of problems and how protective measures should be implemented, have proven unable to provide an effective response to this issue. The monopoly of risk diagnosis by experts in traditional normal science domains surely can be questioned. Today, scientists can not ensure certainty of risks, and they need to share their skepticism with society (Hom et al. 2009, p. 266). In addition, with equivocal findings from different experts and various interpretations of controversial issues, we are convinced that any form of one-way risk management (including risk communication) is not feasible. In other words, one-way communication from government bureaucrats to the public will not be acceptable any more. We will continue to observe new scientific evidence on the grounds of the progress of ideas, and new social advocacy will be based on the consequences of such progress. There will be a continual confrontation between the two. Facing the controversy of meteorological radar and the potential negative effects it may have on human health in this case from Chigu, public participation and transparency of the management process should be included in the risk governance policy, which is the formation of the basic concept of local risk governance. This local risk governance is situated in a broader context of global risk governance. Under the common interests of human society, we need a new model of risk governance across different disciplines that is inclusive of various stakeholders' participation in shaping the definitions and solutions of the problems. Increasing the transparency of the decision-making process, building public participation in the decision-making model, and distinction between scientific risk assessment and risk management/governance has become an important trend (Löfstedt 2003).

Finally, the emerging global challenges arising from the rapid development of science and technology across borders as well as threat or risk disaster areas have resulted in Western technocrats tasting the bitter fruit of the public's mistrust in relevant technological and risk policies (Löfstedt 2003). Controversies about EMF from radar stations, such as the case studied in the present paper, or from other sources, such as mobile phone and base stations, show how a lack of scientific evidence and social consensus may provide us with an opportunity to discuss issues of risk governance for new technologies in Taiwan as well as the Asia-Pacific region.

Acknowledgements. This paper is based on the results from the research project 'Risk of new technology, environmental controversy and risk governance – applying "Consensus Conference" as a model of risk governance for EMF controversy of weather radar in Chigu', funded by the National Science Council in Taiwan (100-2410-H-426-001-MY2). I gratefully thank Karen Cronin, Tomiko Yamaguchi, Darryl Macer, Christopher Nelson, and the anonymous reviewers for providing helpful comments on earlier drafts of this article.

LITERATURE CITED

Ahlbom A, Feychting M, Green A, Kheifets L, Savitz DA, Swerdlow AJ (2004) Epidemiology of health effects of radiofrequency exposure. Environ Health Perspect 112 (17):1741–1754

Beck U (1999) World risk society. Polity Press, Cambridge

Charnley G, Elliott D (2002) Risk versus precaution: environmental law and public health protection. Environ Law Rep 32:363–366

Crabtree BF, Miller WL (1992) Using codes and code manuals: a template organizing style of interpretation. In: Crabtree BF, Miller WL (eds) Doing qualitative research. Sage, Newbury Park, CA, p 163–178

De Marchi B, Ravetz J (1999) Risk management and governance: a post-normal science approach. Futures 31: 743–757

Diesing P (1982) Science and ideology in the policy sciences. Aldine, New York, NY

Doviak RJ, Zrnic DS (1993) Doppler radar and weather observations, 2nd edn. Academic Press, San Diego, CA

Durant J (1999) Participatory technology assessment and the democratic model of the public understanding of science. Sci Public Policy 26:313–319

Ethridge ME (1987) Procedures for citizen involvement in environmental policy: an assessment of policy effects. In: DeSario J, Langton S (eds) Citizen participation in public decision making. Greenwood, Westport, CT, p 115–132

Farrell KN (2011) Snow White and the wicked problems of the West: a look at the lines between empirical description and normative prescription. Sci Technol Hum Values 36:334–361

Fischer F (2006) Participatory governance as deliberative empowerment: the cultural politics of discursive space. Am Rev Public Adm 36:19–40

Funtowicz SO, Ravetz JR (1985) Three types of risk assessment. In: Shipple C, Covello VT (eds) Risk analysis in the private sector. Springer Verlag, New York, NY, p 132–154

Funtowicz SO, Ravetz JR (1990) Uncertainty and quality in science for policy. Kluwer Academic Publishers, Dordrecht

Funtowicz SO, Ravetz JR (1991) A new scientific methodology for global environmental issues. In: Costanza R (ed) Ecological economics: the science and management of sustainability. Columbia University Press, New York, NY, p 137–152

Funtowicz SO, Ravetz JR (1992) The good, the true and the post-modern. Futures 24:963–976

Funtowicz SO, Ravetz JR (1993) Science for the post-normal age. Futures 25:739–755

Hom AG, Plaza RM, Feijoo SF, Palmen R (2009) From precautionary inadequacy to participatory risk management. Futures 41:260–268

Horlick-Jones T, Rowe G, Walls J (2007) Citizen engagement processes as information systems: the role of knowledge and the concept of translation quality. Public Underst Sci 16:259–278

IARC (Working Group on the Evaluation of Carcinogenic Risks to Humans) (2002) Non-ionizing radiation, Part 1: Static and extremely low-frequency (ELF) electric and magnetic fields. Monographs on the Evaluation of Carcinogenic Risks to Humans, 80. IARC, Lyon

IARC (2012) IARC Monographs on the Evaluations of Carcinogenic Risks to Humans. Agents Classified by the IARC Monographs, Volumes 1–104. http://monographs.iarc.fr/ENG/Classification/index.php

ICNIRP (International Commission on Non-Ionizing Radiation Protection) (2009) ICNIRP statement on the 'guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz)'. ICNIRP, Oberschleissheim

ICNIRP (International Commission on Non-Ionizing Radiation Protection) (2010) Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (1Hz to 100kHz). ICNIRP, Oberschleissheim

IRGC (International Risk Governance Council) (2005) Risk governance: towards an integrative approach (written by O. Renn with Annexes by P. Graham). White Paper I. IRGC, Geneva

Jaeger C, Renn O, Rosa E, Webler T (2001) Risk, uncertainty and rational action. Earthscan, London

Jasanoff S (1990) The fifth branch: science advisers as policy makers. Harvard University Press, Cambridge, MA

Jasanoff S (1997) Science at the bar: law, science, and technology in America. Harvard University Press, Cambridge, MA

Kao SF (2008) Social amplification of risk and environmental collective activism: a case study of Cobalt-60 contamination incident in Taiwan. Int J Global Environ Issues 8: 182–203

Kasperson RE (1992) The social amplification of risk: progress in developing an integrative framework. In: Krimsky S, Golding G (eds) Social theories of risk. Praeger, Westport, CT, p 153–178

King N (1994) The qualitative research interview. In: Cassell C, Symon G (eds) Qualitative methods in organizational research: a practical guide. Sage, London, p 14–36

King N (1998) Template analysis. In: Symon G, Cassell C (eds) Qualitative methods and analysis in organizational research. Sage, London, p 118–134

Klinke A, Renn O (2001) Precautionary principle and discursive strategies: classifying and managing risks. J Risk Res 4:159–173

Klinke A, Renn O (2002) A new approach to risk evaluation and management: risk-based, precaution-based, and discourse-based strategies. Risk Anal 22:1071–1094

Kuhn TS (1962) The structure of scientific revolutions. University of Chicago Press, London

Lee KN (1993) Compass and gyroscope: integrating science and politics for the environment. Island Press, Washington, DC

Lin GH (2008) Dien-Tzi-Kong-Huan (EMF Dread). National Taiwan University Press, Taipei (in Chinese)

Löfstedt R (2003) The precautionary principle: risk, regulation and politics. Process Saf Environ Prot 81:36–43

Lotz WG, Rinsky RA, Edwards RD (1995) Occupational exposure of police officers to microwave radiation from traffic radar devices. Natl Tech Inf Serv Publ No. PB95-261350. National Institute for Occupational Safety and Health, Cincinnati, OH

Majone G (2002) What price safety? The precautionary principle and its policy implications. J Common Mark Stud 40:89–109

O'Connor M (1999) Dialogue and debate in a post-normal practice of science: a reflection. Futures 31:671–687

O'Riordan T, Cameron J (eds) (1994) Interpreting precautionary principle. Earthscan, London

Perrow CA (1994) Normal accidents. Basic Books, New York, NY

Ravetz JR (1971) Scientific knowledge and its social problems. Clarendon Press, Oxford

Ravetz JR (1986) Usable knowledge, usable ignorance: incomplete science with policy implications. In: Clark WC, Munn RC (eds) Sustainable development of the biosphere. Cambridge University Press, Cambridge, p 415–432

Renn O (2004) The challenge of integrating deliberation and expertise: participation and discourse in risk management. In: MacDaniels TL, Small MJ (eds) Risk analysis and society: an interdisciplinary characterization of the field. Cambridge University Press, Cambridge, p 289–366

Renn O (2008) Risk governance: coping with uncertainty in a complex world. Earthscan, London

Renn O, Schweizer PJ (2009) Inclusive risk governance: concepts and application to environmental policy making. Environ Policy Governance 19:174–185

Rosa EA (1998) Metatheoretical foundations for post-normal risk. J Risk Res 1:15–44

Rowe GL, Frewer J (2000) Public participation methods: a framework for evaluation. Sci Technol Hum Values 25: 3–29 doi:10.1177/016224390002500101

Savadori L, Graffeo M, Bonini N, Lombardi L, Tentori K, Rumiati R (2007) Rebuilding consumer trust in the context of a food crisis. In: Siegrist M, Earle TC, Gustcher H (eds) Trust in cooperative risk management – uncertainty and skepticism in the public mind. Earthscan, London, p 159−172

Skillington T (1997) Politics and the struggle to define: a discourse analysis of the framing strategies of competing actors in a 'new' participatory forum. Br J Sociol 48: 493−513

Stern PC, Fineberg H (1996) Understanding risk: informing decision in a democratic society. National Academy Press, Washington, DC

Susskind L, Mackearnan S, Thomas-Larmer J (eds) (1995) The consensus building handbook: a comprehensive guide to reach agreement. Sage, Thousand Oaks, CA

Tuler S, Webler T (1995) Process evaluation for discursive decision making in environmental and risk policy. Hum Ecol Rev 2:62−74

Tuler S, Webler T (1999) Voices from the forest: what participants expect of a public participation process. Soc Nat Res 12(5):437−453

Turnpenny J, Jones M, Lorenzoni I (2011) Where now for post-normal science? A critical review of its development, definitions, and uses. Sci Technol Hum Values 36: 287−306

van der Sluijs JP, Matthieu C, Funtowicz S, Kloprogge P, Ravetz J, Risbey J (2005) Combining quantitative and qualitative measures of uncertainty in model-based environmental assessment: the NUSAP system. Risk Anal 25: 481−492

Webler T (1995) 'Right' discourse in citizen participation: an evaluative yardstick. In: Renn O, Webler T, Wiedemann P (eds) Fairness and competence in citizen participation: evaluating new models for environmental discourse. Kluwer Academic Publishers, Dordrecht, p 35−86

Webler T (1999) The craft and theory of public participation: a dialectical process. J Risk Res 2:55−71

Webler T, Levine HR, Renn O (1991) The group Delphi: a novel attempt at reducing uncertainty. Technol Forecast Soc Change 39:253−263

Webler T, Tuler S, Krueger R (2001) What is a good public participation process? Five perspectives from the public. Environ Manag 27:435−450

WHO (World Health Organization) (1999) Electromagnetic fields and public health radars and human health. Fact Sheet 226. WHO, Geneva. Available at: https://apps.who.int/inf-fs/en/fact226.html

Editorial responsibility: Tomiko Yamaguchi, Tokyo, Japan; Karen Cronin, Wellington, New Zealand; and Darryl Macer, Bangkok, Thailand

Submitted: July 11, 2011; Accepted: January 29, 2012
Proofs received from author(s): April 24, 2012