

TAKING RISK SERIOUSLY: A NARRATIVE ANALYSIS OF THE CONTROVERSY OVER ONTARIO POWER GENERATION'S DEEP GEOLOGIC REPOSITORY

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Abstract

Controversies over technologies with uncertain risks, such as deep geologic repositories (DGRs) for nuclear waste, are some of the most divisive current societies face. In their approach to policy controversies, Schön and Rein (1994) elaborate how communities of meaning frame issues in ways oriented to different underlying narratives. Cultural theorists of risk similarly observe that socio-cultural groups understand risk in diverse ways according with plural socio-technological worldviews. Yet while these divisions can seem intractable, it may be possible to develop pragmatic solutions to policy controversies by looking for broader “metanarratives” according to which plural policy narratives make sense simultaneously (Roe, 1994). Interpretive Policy Analysis (Yanow 2000) is used to anatomize the policy controversy around Ontario Power Generation's (OPG's) projected DGR represented in the public dialogue between OPG and a community action organization, Stop the Great Lakes Nuclear Dump (STGLND). Intensity- and theory-driven coding of environmental review submissions, public relations documents, and media quotations found congruencies between these organizations' discourses and Buss et al's techno-optimistic Worldview A and techno-pessimistic Worldview B (1986). Underlying narratives was observed in OPG's discourse on the capability of good geology identified by expert scientists to contain nuclear waste and in STGLND's discourse concerning the vulnerability of water to contamination by nuclear waste and the need for ordinary citizens to protect it. Subsequently, Roe's narrative policy analysis is used to coordinate these underlying narratives by means of a metanarrative that is entitled Responsible Geology and that reflects the prudent middle-ground attitude of some geologists that DGR is a viable approach to nuclear waste management but DGR siting entails more extensive, empirical, and publicly accountable forms of study. This name has deliberate echoes with the Responsible Innovation approach that aims to facilitate more constructive and courageous citizen oversight of technology development (Stilgoe, Owen, and Macnaghten, 2003).

1. Introduction

The question of what to do with nuclear waste (NW) is, apart from a complex technical one, also a complex political one, engaging polarized policy communities with highly different attitudes about desirable socio-technological futures and the appropriate way to assess and manage technological risks. Internationally, there is slow movement in the development of technological solutions for storing NW over the long term, with siting processes vulnerable to paralysis and reversal. At the point of writing this paper (April 2016), the siting process around a DGR proposed by Ontario Power Generation (OPG) for low and intermediate level (L&IL) NW is stalled, with the newly elected government currently asking for more detail on the project from OPG despite its having passed its environmental assessment and licensing review. This project is controversial because it was reportedly first proposed to OPG by the host community, the

Municipality of Kincardine, and later endorsed in a survey of community acceptance as a safer long-term way to dispose of NW currently stored above ground in the municipality near the Bruce nuclear power plant[1]. The location of the proposed DGR proximate to Lake Huron has, however, aroused concern over its potential to leak radioactive contaminants into Lake Huron, leading to organized opposition by numerous environmental and community action groups from the surrounding area, including Stop the Great Lakes Nuclear Dump (STGLND). In November 2012, STGLND launched a petition calling for a precautionary ban on disposing NW in the Great Lakes basin that has garnered international attention and collected almost 100,000 signatures[2].

The controversy around the DGR is representative of other environmental policy controversies, displaying a typical opposition of attitudes around risk between what Yanow has called plural “communities of meaning” [3, p. 11]. One community of meaning, including OPG, the Joint Review Panel that approved the DGR, and a majority of surveyed residents of the Municipality of Kincardine, has confidence in the ability of geologists and engineers to site and design a DGR that will contain NW sufficiently well to protect ecological features, including Lake Huron, from the risk of contamination. Another community of meaning, including environmental non-governmental organizations (NGOs) such as Greenpeace Canada, community action groups such as STGLND, and local as well as international signatories of the STGLND petition opposed to the DGR, believes geologists and engineers cannot sufficiently rule out the risk of a dangerous leak of NW from a DGR into Lake Huron. These two positions of confidence and skepticism in the capability of science and engineering to competently undertake manage complex centralized technological projects involving risk reproduce a typical bifurcation amongst socio-technological worldviews observed for at least thirty years in North America.

Yet despite the opposition between these two positions, it has been suggested that both of these risk attitudes regarding DGRs can be supported within what Roe calls a single “metanarrative” [4, p. 4] that respects both as valid, and which has been named Responsible Geology. This metanarrative, which has validity insofar as it is the stated position of several highly respected geologists in the field of DGRs, simultaneously reflects the importance of persisting in the pursuit of good DGR sites and the importance of continuing to improve the empirical basis upon which those sites are specified. It has been proposed that the Responsible Geology metanarrative offers a basis for policy-makers to make NW controversies more “pliable to policy intervention” by taking the risk attitudes of both communities of meaning seriously and providing the grounds for a diminishment of the grounds of the conflict between them [4].

2. Literature on NW controversies

Numerous scholars have investigated the political controversies around NW disposal and attempted to characterize the risk perceptions and political discourses involved. As well, many well-known researchers of technological and environmental risk attitudes and policy controversies make at least passing reference to public dilemmas over NW and/or nuclear power, including Slovic [5], Beck [6], Wynne [7], and Fischer [8]. Researchers approach attitudes towards NW risk from many disciplinary and political angles, but common amongst them is to characterize these risk attitudes as being divided along expert and public lines, with experts regarding risk in a highly rational, probabilistic, and universalized way, and the public understanding risk in a more intuitive, heuristic-based, placed-based, and/or value-laden fashion.

Depending on the standpoint of the researcher, these types of analyses of NW controversies tend to provoke three types of remedies. On the one hand, scholars such as Slovic favor communications that can help raise the level of the public's understanding of nuclear risk to that of experts. This approach is to some degree pursued in NW policy in Canada, with the Canadian Nuclear Safety Commission having a mandate "to disseminate objective scientific, technical and regulatory information to the public" [9]. Other scholars specifically concerned with the politics of NW such as Kemp [10] and Flüeler [11] favor optimized forms of public engagement that will incorporate the public's views into policy decisions and thereby smooth some of the friction around decision-making. This is the approach generally followed in relevant legislation in Canada such as the Canadian Environmental Assessment Act (2012) and the Nuclear Waste Management Act (for high level NW), both of which include scope for consulting interested persons amongst the public before decisions concerning the siting and licensing of NW management technologies are ultimately made by the federal agency or by cabinet [12]. Finally, researchers such as Fuji-Johnson [13] favor more fully empowering processes of public deliberation such that deliberating bodies of the public are given more decisionary control over the outcome of NW decisions.

The tension between these different approaches to environmental decision-making percolate through NW policy controversies, with different policy communities calling for different types of expert and public voices to be included and prioritized to different degrees. That NW controversies frequently slide from questions of risk to questions of representation is not surprising, since as Buss *et al* found, those holding different technological risk attitudes also tend to prefer different processes for making socio-technological decisions [14]. The correlation between risk attitude and decisionary preference raises questions as to whether alterations in the decisionary process are capable of spurring meaningful remediations of the NW policy conflict, or whether they are more likely to tip decisionary outcomes from favoring one type of risk attitude to another.

3. Cultural theories of risk

A problem with the standard approach to risk controversies as reflecting an opposition between experts and the public is that it mystifies to some degree whether a large turnout of interested citizens claiming to represent public concerns about a project actually do so, or whether they rather reflect a specific cultural segment of it that is concerned. In the latter case, the meaningful division around risk controversies such as that over NW would not fall between experts and the public, but rather between a portion of the public that is more-or-less comfortable entrusting

experts to make decisions about complex technologies such as NW and a portion that is not comfortable doing so. This is essentially the position put forth by a previously marginal, but increasingly respected, segment of researchers working on cultural theories of risk. This approach was initiated by Douglas and Wildavsky, who observed that different contemporary socio-cultural groups focus on largely arbitrary sets of risks, and theorized that risks have the same function for these groups that anthropological “taboos” do for primitive tribes, which is to solidify socio-cultural in-group/out-group boundary and authority structures [15]. In 1982, Douglas and Wildavsky could already identify the presence of two distinctive socio-cultural groupings in the United States with opposed socio-technological views and risk concerns. On the one hand, hierarchists and individualists at the social “center” “ignore long-term risks and low-probability ones”; on the other hand, “egalitarians,” who include founders and members of environmental organizations, “win adherents if [they] can threaten bigger dangers and associate them more convincingly to the corruption of the outside world” [15, p. 122].

Other cultural theorists in the 1980s also observed a bifurcation of the public into two broad socio-cultural communities with common socio-technological aspirations and risk anxieties. Buss *et al* summarized how one major socio-cultural swath researchers called the cornucopian position, the exemptional worldview, and Worldview A, favored economic growth and the intensive use of natural resources and attributed low risks and high benefits to complex centralized technologies such as nuclear power [14, p. 97]. The other major socio-cultural swath called the catastrophic position, the ecological worldview, and Worldview B, favored a shift towards non-material values and attributed high ecological and social risks and low social benefits to centralized technologies such as nuclear power. Buss *et al* also found that adherents to Worldview A preferred rational and institutional approaches to technological decision-making such as Cost Benefit Analysis, while adherents to Worldview B preferred community-based, holistic approaches [14, pp. 115-116].

Worldview A • A high-growth, high technology society provides the best hope for raising the poor to a high state of material and social well-being. • The ability to achieve human goals has been and will continue to be made possible through economic growth and technological progress. • Hard-headed rationality should be the basis of decision making in society. • Although centralization may cause some problems, it is needed in our society for efficient production and management.
Worldview B. • The social and environmental costs of continued technological growth and rising per capita energy consumption are intolerably high. • The “new scarcity” (of physical resources, waste-absorbing capacity of the environment, resilience of planetary life support systems) is <i>qualitatively different</i> from the scarcity problems “solved” by modern industrial production. • Decision making in our society should be made as participative as possible and guided more by humane criteria. • Decentralization of technology and of population is necessary if we are to have a just and free society.

excerpted from Buss et al (1986), pp. 99-100

Figure 1 Contemporary Worldviews, Buss et al (1986)

The continued relevance of the cultural theory of risk can be observed in the highly regarded research on the cultural basis of risk cognition being done by Kahan *et al* in the Cultural Cognition program at Yale, which uses an adapted version of Douglas and Wildavsky’s cultural

categories to study significant divergences in risk attitudes between hierarchical-individualists and egalitarian communitarians in U.S. society towards nuclear power, climate change, and gun ownership[16].

Cultural theorists of risk uphold the importance of public deliberation for the purpose of navigating cultural pluralism [17, p. 144]. However, in their characterization of risks as primarily selected by communities for group-binding functions, cultural theorists of risk have also opened up doubts in the effectiveness of public deliberation for mediating risk issues, highlighting how cultural risk attitudes tend to be self-reinforcing and progressively polarizing rather than amenable to change through communicative measures such as education or deliberation. For instance, Kahan *et al* have observed how subscribers to different socio-technological worldviews attribute greater authority to statements by experts who share their worldviews than those by experts who contradict them [18]. This tendency of people to weigh scientific authority prejudicially reinforces confirmation bias and diminishes the possibility that members of socio-cultural communities can be prompted to update their views on polarized issues either by informational resources that contradict what they already believe or through deliberation with members of different cultural groups.

4. Policy frame theory

In their somewhat pessimistic approach to policy controversies, cultural risk theorists echo the concerns of policy frame theorists, in particular Schön and Rein. According to these theorists, people use “metacultural frames” to guide their policy views [19, p. 34]. These frames are animated by different “generative metaphors” that lead them to select, evaluate, and prioritize different types of information on policy topics and to favor different normative approaches and solutions [19, p. 26]. Schön and Rein also describe it as difficult for holders of plural policy frames to engage constructively with each other, as they interpret and prioritize relevant elements of policy issues in such different ways. To overcome paralyzing policy controversies, Schön and Rein propose that policy communities need to reflect on the limits of their own frames and be open-minded towards others’, akin to Kuhn’s description of translation between scientific paradigms; yet they also regard it as possible that such processes of frame reflection may not happen spontaneously [p. 19, 46, 40].

5. Interpretive Policy Analysis

In order to facilitate reflection on policy frames and the resolution of policy controversies, Yanow as well as Fischer call for researchers or practitioners to undertake Interpretive Policy Analyses that shed light on underlying narratives and other discursive features of policy discourses held by relevant communities of meaning. This study accordingly began with an interpretive policy analysis of OPGs and STGLND’s communication about the OPG DGR, on the basis that these organizations were suitable representatives of wider socio-cultural communities involved in the DGR controversy. The artefacts I studied were submissions of the groups to the public hearings in the OPG DGR environmental review; web-based public relations materials including web-published brochures, FAQs, timelines; and other web documents linkable through OPG’s and NWMO’s websites and through STGLND’s Facebook page. All of the analyzed materials were published between November 2012, when STGLND launched its petition against the OPG DGR, and November 2015, when the newly elected Government of Canada announced it was delaying its decision on the DGR. In total 36 documents were coded to

identify seven types of discursive features: feelings (F); norms (N);beliefs (B) including common-sense as well as evidence-based speculations;storylines (S), consisting of interpretations of the policy situation; generative metaphors (GM) consisting of symbolic expressions; and synechdoches (SY) consisting of comparisons. A tabulated version of the results of the coding is presented in Figure 2.

Ontario Power Generation Feelings • Fortuiteness in geology • Confidence in geology • Confidence in EIS • Pleasure with JRP's decision Norms • Assessed risks should be measurable • Conservative risk assessment • Rely on scientific expertise • Use international best practices • Protect people and environment • Majoritarian community acceptance • Ontarians responsible for NW • OPG responsible for disposing NW Beliefs • Site geology will contain NW • DGR will produce no adverse effects • Any rad doses would be below regulatory limits • NW is manageable. • Storage in a DGR is safest • L& ILW is of low concern Storylines • Residents are comfortable with NW • Those opposing DGR are in minority Generative Metaphor • Deep rock can isolate NW from life Synechdoches • Other DGRs successfully sited near N plants • Lessons can be learned from other DGRs • Knowledge of past geology can predict future	Stop the Great Lakes Nuclear Dump Feelings • Preciousness of Great Lakes • Concern about DGR proximity to Lakes • Shock at OPG's siting process • Disappointment with JRP's decision Norms • Precautionary approach to risk • Avoid low probability severe risks • Avoid excessive confidence in science • Use "Common sense" • National duty of stewardship • Broad based community acceptance • NW risk should be distributed fairly • OPG shouldn't "abandon" NW Beliefs • Geological behavior not predictable • Other DGRs have failed • Any measurable rad leak would harm lakes • NW is exceptionally toxic • DGR technology is unproven • ILW almost as dangerous as HLW Storylines • Kincardine is in conflict of interest • Public at large is opposed to Generative Metaphor • Artificial NW threatens natural water Synechdoche • Failures of other DGRs predict failure of this one
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Figure 2 Results of coding the discourse of OPG and STGLND

In analyzing the discursive features, the generative metaphors were taken as the starting point, in keeping with Schön and Rein's view that these features underlie and determine other features of policy discourse. As Schön and Rein discuss, a policy community's "framing" of a situation first proceeds through the selection of a generative metaphor that seems symbolically applicable to the situation and that "derives its normative force from certain purposes and values, certain normative images, that have been powerful in our culture"[19, p. 27].

In OPG's discourse, the most evocative symbol was that of the geological rock intended to host the DGR, the stability and reliability of which was emphasized at every turn in resonant imagery such as a "blanket," a "cap," and a "seal." *Well-chosen geological rock can isolate and contain NW* was discerned to be the generative metaphor underlying OPGs discursive content overall. OPG's generative metaphor was in turn observed to echo longstanding cultural narratives in which nature is beneficent, robust, and capable of supporting virtuous human enterprises. OPG's adoption of this generative metaphor could in turn be seen permeating its other beliefs, such as

that DGRs are the safest way to store NW and that the Environment Impact Assessment's conclusion that there would be no adverse environmental effects from this DGR could be trusted.

For STGLND, the most symbolically resonant image was the water of the Great Lakes, which was recurrently presented in a way that suggested it was pure and unsullied by human presence. STGLND's generative metaphor was therefore discerned as: *Artificial NW can contaminate natural water*. This generative metaphor was in turn observed to connect with the longstanding cultural tradition of distrust in the artificial and protective concern for vulnerable nature that is associated with Romanticism[19, p. 28]. STGLND's adoption of this generative metaphor was seen permeating its other beliefs, such as that NW is exceptionally toxic and that the DGR technology is doubtful and prone to failure.

As Schön and Rein indicate, generative metaphors at the heart of policy frames provide the basis for a "normative leap" prescribing how policy situations should be dealt with[3, p. 43][19, p. 26]. OPG's generative metaphor that rock can isolate and contain NW accordingly determines the norms it regards as paramount for decision-making around NW, including the need to make use of experts, science, conservative risk assessments, and international best practices to ensure a given geological formation is suitable. By contrast, STGLND's generative metaphor that natural water is threatened by artificial NW emphasizes the fallibility of scientific experts and practices and introduces a normative requirement of including in decisionary practices members of the public who can safeguard nature because they have "common sense" and value nature in a more intuitive and place-based way.

6. Cultural worldview analysis

As the interpretive policy analysis displayed, many of the features of OPG's and STGLND's discourse, including beliefs, norms, feelings, and stories, were opposed. Cultural theories of risk further revealed that the beliefs and norms expressed by OPG and STGLND align with broader longstanding socio-cultural worldviews, summarized by Buss *et al* as Worldview A and Worldview B see section 3. The beliefs and norms of OPG that nuclear benefits outweigh the risks and that scientists should be entrusted to make decisions concerning these projects were congruent with Worldview A. The beliefs and norms advanced by STGLND that the risks of NW to the environment are too high to be borne and that the public ought to be empowered to make decisions about socio-technological futures were congruent with Worldview B.

Continuity between the discourses of OPG and STGLND with longstanding worldviews concerning socio-technological futures, acceptable technological risks, and preferable decision-making processes raises doubt that public deliberation, on its own, can ever remediate the OPG DGR policy controversy. Instead, it suggests that more public deliberation would likely tilt outcomes towards the sociotechnological preferences associated with Worldview B by ensuring technology policy decisions are made in keeping with holistic community values rather than with rationalistic procedures such as cost benefit analysis (CBA) and comparative risk assessment (CRA), which members of Worldview A prefer. Fuji-Johnson, an advocate of empowered public deliberation around NW options writes that "precautionary reasoning is necessarily implicit in the deliberative ideal" [13, p. 92]. Because the precautionary principle puts the burden of proof on proponents to prove projects will never be harmful, and DGR proponents

cannot with complete certainty do so due to the long time spans involved, DGRs may never be found acceptable in deliberative forums [13, p. 87].

Critics of the precautionary principle point out that the precautionary reasoning that militates against technological mistakes also closes down opportunities for technological benefits that mitigate other risks[20]. Given that risks, understood broadly, may be increased through either a shortfall or an excess of precautionariness, founders of the Responsible Innovation approach hold that “principles should not be treated as decision procedures” [21, p. 61]. If the wider use of public deliberation processes for technological decision-making would lead to a predominance of precautionary outcomes, this may be the best reason to continue to weave such processes together with rationalistic processes such as CBA and CRA, which can be useful for surfacing unintended consequences and risks of policy action as well as inaction[22].

7. Framing the policy metanarrative

The results of the Interpretive Policy Analysis and the Cultural Worldview Analysis did not indicate how to remediate the entrenched discursive divisions falling between OPG and STGLND. Rather, they confirmed the division was likely to be rigid and intractable, given its roots in a longstanding historical argument. Accordingly, another approach to mediating policy divisions was undertaken called narrative policy analysis, which is based on structuralist literary theory. Roe devised narrative policy analysis to nudge forward policy controversies characterized by a high degree of uncertainty, complexity, and polarization[4, pp. 2-3]—all of which aptly diagnose the OPG DGR policy controversy. Roe proposes that, given the degree of complexity and uncertainty in such controversies, there are diminishing returns in trying to determine which of the policy actors’ narrative of the issue is the most accurate. Even if the analyst believed he or she had identified the more accurate narrative, due to the polarization of the issue others would be unlikely to be persuaded and the policy issue would continue to be intractable [4, p. 10]. Instead, Roe outlines a process of reflecting on diverse policy narratives to discover an alternative “metanarrative,” according to which all of the prevailing policy narratives are true, which can provide grounds upon which pursue the policy debate in a more constructive fashion [4, p. 18].

Narrative policy analysis begins with assembling the key narratives about the policy issue. In my narrative analysis of the OPG DGR, I decided to focus on the generative metaphors concerning the DGR, insofar as generative metaphors, being “tacit” or unconscious, seemed likely to be close to what the policy communities really valued and believed [19, p. 34]. Moreover, the generative metaphors of the two groups, though framing the policy situation of the OPG DGR in opposing ways, were not incongruent with each other. It is at once true that the rock in which the DGR is built will probably isolate the NW, as OPG holds, that the NW might possibly contaminate the water, as STGLND holds. The difference between these generative metaphors rests in which aspect of the situation they frame their focus: the robust rock and the probability that it will perform as projected, or the vulnerable water and the possibility that it will be contaminated by the NW. Accordingly, a metanarrative could be developed that holds true for both communities of meaning: *Sited in a geologically good site proximate to a water body, a DGR probably could contain the NW, but possibly could leak and contaminate the water.* I would call this metanarrative template “cautionary” but not “precautionary,” since it emphasizes the probability of success as well as the possibility of failure and points towards the desirability of closing the uncertainty gap between these two prospects.

8. Finding the intertext for the policy controversy

Ultimately, for Roe, a “metanarrative,” is found in an “intertext,” an originating text that is tacitly acknowledged by all of major policy narratives, or in the words of the literary theorist Riffaterre, a “reference without which the text[s] would not make sense” [24, p. 169]. To find the intertext, other less conspicuous narratives related to the DGR OPG were examined to discover if any resembled the metanarrative. One such narrative was found in statements STGLND quoted by two well-respected geologists in the field of DGRs, Allison Macfarlane, the former director of the U.S. Nuclear Safety Commission, and William Fyfe, an internationally recognized DGR researcher. Both of these geologists’ statements, and their overall bodies of writing, hold that DGRs sites are worth pursuing but need to be pursued with an unparalleled degree of caution.

As MacFarlane wrote in a 2006 volume she co-edited on the proposed Yucca Mountain DGR, “Geology has not advanced far enough yet to expect that it can [predict reactions into the geological future through the use of models]” [26, p. 397]. MacFarlane’s point is not to quash the DGR concept but rather to augment the scientific models used for siting with empirical data from other sites and from further tests. Her position is, like the metanarrative template, cautionary but not precautionary, calling for ongoing reduction of the uncertainties around DGR siting through an increase of the evidence base. Fyfe’s position on DGR siting was captured in his press statement that “[y]ou do not put nuclear waste near things like the Great Lakes or the Great rivers in case there’s a leakage you haven’t expected” [27]. This seemingly precautionary statement is given context amidst Fyfe’s larger body of writing on the issue of DGR siting, which is, like McFarlane’s, not averse to DGR technology but rather insistent on the importance of developing a sound empirical basis for siting. As Fyfe has stated, he “believe[s] that nuclear waste can be managed securely” in DGRs [29]. Further, in a 1984 article in *Nature*, an International Council of Scientific Unions committee on DGRs siting, of which he was a member, called for extensive “geological studies related to proposed methods, materials, etc.,” including through “development of underground laboratories in all rock types” [28, p. 540]. The Council also argued for the “need to consider the problem of how a major leak from a repository might be detected and treated.”

Fyfe’s and McFarlane’s positions overall reflect a cautionary—though not precautionary—concern with the need for more extensive study of the factors involved in DGR siting. Accordingly, these geologists provide direction for how the reduction of uncertainty called for by metanarrative may be undertaken. The metanarrative for the OPD DGR policy controversy was accordingly named the Responsible Geology narrative. The Responsible Geology metanarrative, which has evidently been around for several decades, satisfies Roe’s condition that a policy metanarrative be implicitly referred to by a range of divergent policy narratives concerning an issue, and as such offers a methodological and normative touchstone for policy communities that are opposed on so many other points. In this regard, the Responsible Geology metanarrative can be seen to underlie both OPG’s norms regarding the need for a great deal of exacting geological study before siting a DGR, as well as STGLND’s norms regarding the importance of protecting ecologies and water bodies from radioactive contamination. The name of the Responsible Geology narrative was deliberately chosen to echo the Responsible Innovation approach, an emerging framework for productive discussion on technological innovation with touchstones in both evidence and in public values [25].

9. Conclusion: Taking Risk Seriously

As Roe describes, the purpose of policy metanarratives is not to cultivate a consensus but rather to render “seemingly intractable problems into ones more amenable to solution” through “uncertainty reduction, complexity simplification, and depolarization” [4, p. 18]. In that regard, the Responsible Geology metanarrative may be used to help devise empirical processes to reduce the uncertainty in relation to DGRs, which can be conceptualized as the gap between the probabilistic scenario of technological success emphasized by OPG and the possibilistic scenarios of technological failure emphasized by STGLND. While it is possible this gap may never be eliminated in a way satisfactory to all stakeholders, aiming to diminish it appears to be a suitable goal for policy makers to orient policy processes. Although such a process may not hasten the development of NW management facilities in the short term, more constructive and inclusive styles of engaging the public in the conceptualization and siting of facilities such as these may lead to cumulatively less polarization around complex technologies such as nuclear power and NW management facilities over the long term.

Policy-makers, researchers, and stakeholders in technology risk negotiation processes are accordingly called upon to move on from reinforcing polarizing and paralyzing framings of risk attitudes in terms of a fundamental breach in risk cognition between experts and citizens for which the only solutions envisionable are communicative; that is, education and/or deliberation. Instead, this analysis suggests a more constructive approach would be to 1) take risk and attitudes towards it seriously as reflective of the diverse concerns and values of plural sociocultural groups; 2) to use deliberation processes to reveal these underlying concerns and values; and 3) to emphasize specific dialogue processes as well as research projects oriented towards bridging polarized sets of values, beliefs, and norms. Such an approach would more adequately recognize the likelihood that neither Worldview A's priorities of technological and economic progress, nor Worldview B's priorities of averting environmental and human health risks will become outmoded in the near future, and an acceptance that each of these cultural worldviews has a role to play in designing our technological futures. In particular, such an approach is in keeping with the Responsible Innovation approach, which sees a need for public engagement processes specifically designed to bring to light public values regarding technology innovation, in part as a first step towards facilitating the negotiations and trade-offs likely to be required in this era of accelerating technological innovations as well as requirements [30].

10. References

- [1] Ontario Power Generation, "Frequently Asked Questions about OPG's Deep Geological Repository for Low- and Intermediate-Level Nuclear Waste," February 2016. [Online]. Available: <http://www.opg.com/generating-power/nuclear/nuclear-waste-management/DGR%20pdfs/FAQs.pdf>. [Accessed 30 April 2016].
- [2] Stop the Great Lakes Nuclear Dump Dump, "Stop the Great Lakes Nuclear Dump Petition," GoPetition, 24 November 2012. [Online]. Available: <https://www.gopetition.com/petitions/stopthegreatlakesnuclearDump.html>. [Accessed 30 April 2016].
- [3] D. Yanow, *Conducting Interpretive Policy Analysis*, Thousand Oaks, CA: Sage, 2000.
- [4] E. Roe, *Narrative Policy Analysis*, Durham, NC: Duke UP, 1994.

- [5] P. Slovic, "Perception of Risk from Radiation," *Radiation Protection Dosimetry*, vol. 68, no. 3/4, pp. 165-180, 1996.
- [6] U. Beck, *Risk Society*, Thousands Oaks, CA: Sage, 1986.
- [7] B. Wynne, *Rationality and Ritual: Participation and Exclusion in Nuclear Decision-Making*, 2nd edition, London, UK: Earthscan, 2012, pp. 44-83.
- [8] F. Fischer, *Citizens, Experts, and the Environment: The Politics of Local Knowledge*, Durham, N.C.: Duke UP, 2000.
- [9] Canadian Nuclear Safety Commission, "Introduction to Radiation," 03 February 2014. [Online]. Available: <http://nuclearsafety.gc.ca/eng/resources/radiation/index.cfm>. [Accessed 30 April 2016].
- [10] R. Kemp, *The Politics of Radioactive Waste Disposal*, New York, NY: Manchester UP, 1992.
- [11] T. Flüeler, *Decision Making for Complex Socio-Technical Systems: Robustness from Lessons Learned in Long-Term Radioactive Waste Governance*, Amsterdam, NL: Springer, 2006.
- [12] Canadian Environmental Assessment Agency, "Basis of Environmental Assessment," 25 March 2015. [Online]. Available: <https://www.ceaa-acee.gc.ca/default.asp?lang=En&n=B053F859-1>. [Accessed 30 April 2016].
- [13] G. Fuji Johnson, *Deliberative Democracy for the Future: The Case of Nuclear Waste Management in Canada*, Toronto, ON: U Toronto P, 2008.
- [14] D. M. Buss, et al, "Contemporary worldviews and perception of the technological system," in *Risk Evaluation and Management*, New York, Plenum Press, 1986, pp. 93-130.
- [15] M. Douglas and A. Wildavsky, A., *Risk and Culture: An Essay on the Selection of Technological and Environmental Dangers*, Berkeley, UC: U California P, 1982.
- [16] D. Kahan, et al, "The polarizing impact of science literacy and numeracy on perceived climate change risk," *Nature Climate Change*, vol. 2, pp. 732-735, 2012.
- [17] Douglas, M., Thompson M. and Verweij M., "Is time running out? The case of global warming," in *Cultures and Crises: Understanding Risk and Resolution*, Thousand Oaks, CA, Sage, 2013, pp. 134-145.
- [18] Kahan D., Jenkins-Smith, H., and Braman D., "Cultural Cognition of Scientific Consensus," *Journal of Risk Research*, vol. 14, no. 2, pp. 147-174, 2010.
- [19] Schön, D. A. and Rein, M., *Frame Reflection: Toward the Resolution of Intractable Policy Controversies*, New York, NY: Basic Books, 1994.
- [20] C. Starr, "The Precautionary Principle Versus Risk Analysis," *Risk Analysis*, vol. 23, no. 1, pp. 1-3, 2003.
- [21] J. B. Holbrook and A. Briggie, "Knowledge kills action: Why principles should play a limited role in decision-making," *Journal of Responsible Innovation*, vol. 1, no. 1, pp. 51-66, 2014.
- [22] R. Revesz and M. Livermore, *Retaking Rationality: How Cost Benefit Analysis can Better Protect the Environment and Our Health*, March 2008, New York, NY: Oxford University Press, 2008.

- [23] D. Stone, *Policy Paradox: The Art of Political Decision Making*, New York, NY: Norton, 1988.
- [24] M. Riffaterre, "Relevance of theory/theory of relevance", *Yale Journal of Criticism*, vol. 1, no. 2, pp. 163-78, 1988.
- [25] Stilgoe J., Owen R., and Macnaghten P., "Developing a framework for responsible innovation," *Research Policy*, vol. 42, no. 9, pp. 1568-1580, 2013.
- [26] A. Macfarlane, *Uncertainty Underground: Yucca Mountain and the Nation's High-Level Nuclear Waste*, Cambridge, MA: MIT Press, 2006.
- [27] Canadian News Service, "Ont. nuke waste plan poses Great Lakes risk, U.S. Democrat claims," *Canada.com*, 24 October 2006.
- [28] W. S. Fyfe et al, "The geology of nuclear waste disposal," *Nature*, Vol. 310 No. 16, pp. 537-540, 1984.
- [29] W. S. Fyfe, "Nuclear waste isolation: An urgent international responsibility," *Engineering Geology* Vol. 52, pp. 159-161, 1999.
- [30] B. Taebia et al, "Responsible innovation as an endorsement of public values: the need for interdisciplinary research," *Journal of Responsible Innovation*, vol. 1, no. 1, pp. 118-124, 2014.