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Confronting risks: regulatory responsibility and nuclear energy

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The imperatives of contemporary environmental governance require the minimization and/or the redistribution of risk among persons, peoples, and generations, subject to various tradeoffs and based in several key principles of risk distribution. Especially in cases involving manufactured risks, justice requires that states and societies protect their vulnerable from avoidable anthropogenic risk, and this imperative forms the basis for regulatory responsibility. The ethical issues surrounding risk as they apply to nuclear energy, including those inherent in expanded nuclear development as well as in continued reliance upon non-nuclear sources of electrical generation, are examined. Of particular concern is comparison of the risks associated with nuclear energy and those related to reliance upon carbon-intensive energy sources, including issues of justice in the distribution of risk and the legitimacy of involuntarily imposed risks, such that the potential costs and benefits associated with each of these risk-laden options can be meaningfully compared and the proposal to expand nuclear power as a climate policy tool critically assessed.

Keywords: risk analysis; nuclear energy; environmental governance; risk management

Introduction

Ulrich Beck (1992) identifies the 'risk society' as resulting from the fact that human societies must increasingly be organized around distributing risks, including the *external risks* that arise without direct human causation (for example, from earthquakes or other 'natural disasters') as well as the *manufactured risks* that arise from human choices (for example, from pollution or other anthropogenic environmental hazards). Such risks to human health and welfare cannot be eliminated entirely, but they can be managed, and the threats that they pose can be reduced and redistributed. Risk, Beck (1992, p. 19) argues, is '*ascribed* by civilization' rather than being the product of good

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or bad fortune, and has overtaken scarcity as the core concern of modern social conflict such that the 'new paradigm' of risk society turns on the question: 'How can the risks and hazards systematically produced as part of modernization be prevented, minimized, dramatized, or channeled?' Indeed, contemporary environmental governance has largely become an imperative of minimizing and fairly distributing risk among persons, peoples, and generations, subject to various tradeoffs and normative principles. Where manufactured risks are involved, it is now regarded as an issue of basic justice that the vulnerable be protected from risk generated by human activities, forming the core imperative of regulatory responsibility.

Foremost among current challenges for environmental governance is anthropogenic climate change, which threatens manifold and momentous social and environmental disruptions unless human societies can significantly reduce their greenhouse gas emissions. While there remain considerable uncertainties concerning the relationships between increasing atmospheric concentrations of greenhouse gasses and the various consequences that have been predicted by climate scientists (Intergovernmental Panel on Climate Change [IPCC] 2007b), there remains little genuine doubt that the climatic instability caused by human dependence upon fossil fuels for energy constitutes a critical manufactured risk that demands a concerted and far-reaching human response, if one that defies conventional risk analysis (Pidgeon and Butler 2009). Most agree that this response must include a mix of conservation policy efforts designed to reduce demand for energy along with development of alternative sources of energy to replace carbon-intensive fossil fuels in electricity production and transport sectors. As national governments and environmental non-governmental organizations grapple with the challenges posed by climate change and weigh the policy options for minimizing its harmful consequences, and despite the March 2011 Fukushima Daiichi meltdown, one controversial policy option has reasserted itself into the debate over domestic and global energy and environmental policy: the proposal for significantly expanded reliance upon nuclear power.

The 'nuclear option' in climate policy is controversial for familiar reasons: it generates a set of manufactured risks that are comparable with – if also different from in some practically and conceptually significant ways – those posed by climate change itself. Both involve potentially grave risks for current and future generations, but with their respective risks distributed across different populations and entailing varying levels of probability and uncertainty. Climate change involves moderate and widely dispersed damage estimates at high levels of probability, with uncertainty about the range and extent of impacts, with both probability and severity increasing in a linear fashion with the increase in atmospheric greenhouse concentrations. By contrast, a reinvigorated nuclear energy program involves significantly less probable but more intensified, focused, and certain harm to fewer persons, and with a binary rather than linear risk scale, as risky outcomes either occur or they do not. Some of those threatened by climate change would also be placed at greater risk by expanded reliance upon nuclear energy, but the policy dilemma primarily involves displacing risk from one set of vulnerable subjects to another; that is, expanded reliance upon nuclear power could marginally decrease climate-related risk for large numbers of persons, at the cost of increasing nuclear-related risks for fewer persons. In weighing these two options, further assessment of these differently structured risks is needed so that a normatively defensible response to the dual risks inherent to reliance upon fossil fuels and nuclear energy for electrical generation can be crafted. Some relevant questions in this assessment are technical in nature, but the core of such exercises in risk assessment and response is irreducibly normative, requiring the critical examination of risk and the way that various social goods (including human health and welfare, environmental sustainability, and security) trade off against one another, and how various kinds of risks are balanced and distributed among human populations.

Since the social response to risk involves issues of its just distribution among persons and peoples – or as Beck (1992 p. 35) notes: 'wealth accumulates at the top, risks at the bottom' – its normative analysis requires the application of principles of distributive justice and not merely the standard consequentialist tools of conventional risk assessment. 'As the risk society develops,' Beck (1992, p. 46) notes, 'so does the antagonism between those *afflicted* by risks and those who *profit* with them'. Attention must therefore be paid to how the downside costs and upside benefits are allocated, since risk imposition often benefits some while placing others at greater risk. Processes of control over assignments of risk ought likewise to be considered, for as Kristin Shrader-Frechette (1985, p. 442) notes, standard forms of risk assessment tend to 'ignore the value dimension of policy analysis and to disenfranchise the public who, in a democracy, ought to control that policy'. By reducing all risk to expected aggregate costs and benefits, standard risk assessment ignores problems surrounding the distribution of risk and the asymmetries often involved in risk imposition (Sunstein 2004), and so requires additional evaluative criteria for its justified imposition. Here, I shall consider how the manufactured risks associated with climate change might be compared against those issuing from nuclear energy development, which has been offered as a remedy. In particular, my concern shall be with how these two sets of risks might be compared with one another, such that the potential costs and benefits associated with each of these risk-laden phenomena can be meaningfully compared and the proposal to expand nuclear power as a climate policy tool can be critically assessed. In so doing, I intend to offer an account of risk that takes on what Beck (1992, p. 21) describes as its core meaning, as 'a systematic way of dealing with hazards and insecurities induced and introduced by modernization itself'. Such hazards and insecurities must be dealt with in some manner, and a 'systematic way' of doing so requires that their current production and distribution be subjected to critical scrutiny.

The nuclear option

While nuclear energy production was once anathema to environmental activists, and indeed to the ideological left more generally (Rothman and Lichter 1987), concerns about climate change have led several high-profile green figures to rethink its prohibition. James Lovelock, the British atmospheric scientist that originated the Gaia theory, Stewart Brand of the *Whole Earth Catalog*, and Friends of the Earth founder and director Hugh Montefiore have all recently endorsed nuclear power as a climate-friendly energy option. Greenpeace founder Patrick Moore has done likewise, here summarizing the appeal of a carbon-free energy source in an electricity infrastructure dominated by fossil fuels:

> More than 600 coal-fired power plants in the United States produce 36 percent of US emissions – or nearly 10 percent of global emissions – of CO_2, the primary greenhouse gas responsible for climate change. Nuclear energy is the only large-scale cost-effective energy source that can reduce these emissions while continuing to satisfy a growing demand for power. And these days it can do so safely. (Moore 2006, p. B01)

Some of these claims are contestable, and both the safety and cost-effectiveness of nuclear power shall be further considered below, but the argument's force can be found in its contrast between the climate impacts of nuclear power and that of coal, on which the United States currently relies for the bulk of its electricity production and which nuclear power could potentially replace. Expanded nuclear energy is recommended as the lesser evil, with continued reliance upon coal for electrical generation very likely to bring about catastrophic climate impacts and the downside risks of nuclear accidents seen as worse but less probable. As Bernard Cohen (1983) also argues, Moore suggests that the risks inherent in nuclear energy have been overstated and those associated with climate change understated, such that proper risk analysis would endorse nuclear expansion.

But would it? Clearly, the risks associated with unmitigated climate change are serious ones, and taking them seriously requires fundamentally rethinking the way that humans generate and use electricity, now and in the future. Scientists estimate that cuts of 80–95% from 2000 emissions levels will be required by 2050 in order to stabilize atmospheric concentrations of greenhouse gases at a level that would prevent the 'dangerous anthropogenic interference with the climate system' that was identified as the objective of the 1992 UN Framework Convention on Climate Change (IPCC 2007a, Hansen *et al.* 2008). Updating scientific assessments prior to the 2009 climate meetings in Copenhagen, the International Scientific Congress on Climate Change warned in June 2009 that 'recent observations show that greenhouse gas emissions and many aspects of the climate are changing near the upper boundary of the IPCC range of projections' (Richardson *et al.* 2009, p. 6), raising the prospect of crossing irreversible 'tipping points' in climate impacts earlier than previous forecasts projected. Given the threat of catastrophic and irreversible climate disturbances, with the profound social, political, economic, and ecological costs that these are expected to bring about, all options for decarbonizing the economy must now be placed on the table for consideration, including an expanded US and global nuclear energy program. Eliminating risk altogether, as Beck argues, is no longer a viable option. Both climate change itself and the primary strategies for mitigating its effects involve risk imposition, albeit of different kinds and degrees. Charting the most defensible course between a risky environmental phenomenon and risky decarbonization policy requires the ability to meaningfully compare and effectively manage risk, which in turn requires understanding its normative dimensions.

Proposals to expand nuclear energy are often framed in terms of their potential climate benefits, compared with fossil fuel-intensive electrical generation, and the new landscape of public and elite opinion concerning 'the nuclear option' owes largely to its potential source of 'green' power. To explicate relevant tradeoffs and comparative risks, I shall focus on the case of nuclear energy expansion in the United States, where large-scale electrical generation now accounts for one-third of all greenhouse emissions, where low-carbon energy sources are urgently needed to replace coal-fired power plants, but where nuclear energy development has long been stalled by concern about its risks – a concern that began to cede some ground to worries about climate change mitigation before the Fukushima disaster. There, fossil fuels account for 86% of total energy use and 71% of electricity generation, while nuclear energy accounts for 8% of overall energy, and renewable sources (including hydro, wind, solar and geothermal) together account for 6%. The United States currently operates 103 nuclear reactors, with no new domestic reactor orders since 1978 and the newest reactor (the Tennessee Valley Authority Watts Bar 1, ordered in 1970) coming online in 1996. Reactors are initially granted 40-year operating licenses, but can apply for 20-year license renewals, so if no new reactors are constructed then the first of these 103 nuclear facilities will be decommissioned after its 60-year life-span ends in 2030 and the last US reactor will cease operations in 2056 (Ferguson 2007). Holding energy use and the proportions of non-nuclear domestic electrical generation sources constant, the loss of the power loads of these 103 nuclear plants would increase domestic greenhouse emissions by 6–7%, while a doubling of reactor capacity by 2050 would reduce them by the same amount (Union of Concerned Scientists 2007). While an expanded US nuclear energy program cannot by itself adequately address the threat of serious climate change, it could make a significant dent in its current carbon-based energy portfolio, and in so doing play some role in a larger domestic and international climate policy.

Compared with coal and natural gas-fired power plants, nuclear energy has a significantly higher capitalization cost, a longer lead time to bring new plants online, and approximately 50% higher per-kilowatt generation costs. Barring accidents, it is much lower polluting, both in terms of greenhouse pollutants and other air-borne and water-borne hazardous particulates, but in the event of an accident the potential costs of nuclear power are much higher, and long-term storage needs for spent nuclear fuel generates leakage and security concerns that the US government has yet to adequately address (Rogers and Kingsley 2004). Absent significant government subsidies and possibly unjustified liability limits for nuclear facilities, along with a viable long-term storage solution for depleted uranium, nuclear power cannot compete with the relatively inexpensive fossil fuel technologies in terms of startup and operating costs. Not surprisingly, such subsidies and protections have been aggressively advocated by the nuclear industry, often with climate-related benefits as a primary selling point, and both the 1992 and 2005 Energy Policy Acts have offered billions of dollars in incentives in an effort to jump-start the domestic nuclear industry, thus far to no avail (Ferguson 2007). But the US government *could* provide additional incentives and remove more regulatory obstacles, making expanded nuclear energy an economically viable energy source, if the benefits of doing so outweigh the costs of those incentives and the risks that relegated nuclear energy to pariah status throughout much of the world following the accidents at Chernobyl, Three Mile Island, and now also Fukushima. The question is: *should* they do so? Is the 'nuclear option' worth its several downside costs, the most serious of which involve low probabilities of major harm? On what bases might such a decision be made, and how can the risks associated with nuclear energy be commensurably compared against those of intensified climate change?

Several safety concerns are typically cited in opposition to expanded nuclear energy programs, and a precautionary approach – here understood as a moratorium on further nuclear plant construction until safety concerns can be adequately addressed – is typically defended in light of the uncertainty that surrounds those safety issues. Worries about safety emanating from public opinion have thus far supported what Kerry Whiteside terms a 'precautionary idea' in the context of expanded nuclear energy development, manifesting 'whenever authorities take early preventative measures to forestall a potential, irreversible danger, even though causal links in the chain leading to that danger have not yet been firmly established' (2006, p. 65). US climate change policy, by contrast, has largely followed what Whiteside describes as the 'reflexively anti-precautionary' posture characteristic of its regulatory politics. With nuclear energy, safety concerns – including risks of a reactor meltdown, nuclear material proliferation, contamination from stored nuclear wastes, and terrorist attack – involve the potential for catastrophic and irreversible harm, warranting the precautionary imperative to minimize impositions of risk in light of the potential for catastrophic outcomes. These risks would increase with an expanded nuclear energy program, whether as the result of increases in facilities and volume of materials or through the deregulatory incentives that government has created in order to re-start reactor construction,[1] and must be assessed as such. But similar risks arise from climate change, and such risks would be exacerbated by mothballing existing nuclear facilities and could be reduced by expanding them. In the tradeoff between nuclear energy and fossil fuels, risk is ubiquitous and inescapable; as Beck (1992, p. 31) suggests 'there occurs, so to speak, an overproduction of risks, which sometimes relativize, sometimes supplement and sometimes outdo one another'. No longer can simple precaution point the way toward a defensible resolution of this dilemma, and standard imperatives to minimize risk or maximize expected value are confounded by the way that risks are distributed among parties and over time by both options. If Beck's (1992, p. 80) risk society 'harbors a tendency to a legitimate totalitarianism of hazard prevention', it also suggests that risk itself, along with the goods that make it inevitable, are subject to justice in their distribution. In addition, it points the way to identifying acceptable risks and the compensatory measures needed to justify imposing risk where such imposition is unavoidable. To such issues we shall now turn.

Weighing opposing risks and uncertainties

Anti-nuclear activists frequently point to the possibility of some very bad outcome in defense of a strong precautionary stance against the further development of nuclear power, implicitly claiming that this low-probability but high-cost outcome justifies the rejection of any potential benefits. But does it? At issue is how to compare the high-probability climate benefits of expanded nuclear energy against the small chance of catastrophic harm that expansion risks, and when to forego likely benefits in anticipation of merely possible costs. A precautionary stance against nuclear energy focuses upon its downside risks, foregoing potential benefits in light of those possible costs, and John Harsanyi challenges such a stance in principle. Arguing against the *maximin* decision rule found in the Rawlsian difference principle, he criticizes the decision rule to 'evaluate every policy available to you in terms of the *worst possibility* that can occur to you if you follow that particular policy' (Harsanyi 1975, p. 595), ranking alternatives not in terms of expected benefits but of worst case outcomes. To illustrate the irrationality of a precautionary stance, Harsanyi posits that you live in New York and must choose between a dull and poorly paid job there and an interesting and well-paid position in Chicago. If you take the Chicago job, you would have to fly there the next day, in which case there is a small chance that you would be killed in a plane crash in transit. Presumably, that is your only risk. Your options are thus as presented in Table 1.

Your best and worst options are both possible if you take the Chicago job, but some uncertainty prevents you from knowing which of the two will obtain,

Table 1. Risk option example.

	Chicago plane crashes	Chicago plane does not crash
You choose the New York job	You will have a poor job in New York but will be alive	You will have a poor job in New York but be alive
You choose the Chicago job	You will die	You will have a good job in Chicago and will not die

while you would be certain to have a suboptimal but not worst-case outcome if you opt to remain in New York. If you choose based upon worst possible outcomes, you would have to forfeit the best possible outcome in order to avoid the worst one. Harsanyi (1975, p. 595) argues: 'it is extremely irrational to make your behavior wholly dependent on some unlikely unfavorable contingencies, regardless of how little probability you are willing to assign to them', and indeed this claim as stated is plausible. While it may *sometimes* be rational to sacrifice the potential gains from risk in order to avoid worst cases that are also made possible by it, he is right to claim that it is not *always* so, at least in the type of case he describes here. A sufficiently low probability of the plane crash would lead to higher expected value with the Chicago job, and, just as surely, a high enough probability for the crash would make the New York job a more rational option. Probability is the key to expected value.

Rather than making decisions on the basis of the worst possible outcome, Harsanyi argues that it would be rational for you to employ a Bayesian decision rule and maximize your expected utility. Given the very low probability of your being killed in a plane crash *en route*, he suggests, you should 'take your chances and choose the Chicago job' (Harsanyi 1975, p. 595). The expected value of that option includes the sum of the disvalue of being killed in a plane crash heavily discounted by its very low probability, combined with the value of the better job. If, as Harsanyi suggests, the expected net value of moving to Chicago exceeds that of remaining in New York, it would be irrational to choose otherwise. Here, Harsanyi accurately captures how standard risk analysis is conducted, where outcomes are discounted by probabilities of their occurrence. But what follows from his analysis? Does it provide the requisite analytical tool for comparing the divergent risks inherent in climate change and expanded nuclear energy? As he characterizes the precautionary stance of the maximin decision rule:

> If you took the maximin principle seriously then you could not ever cross a street (after all, you might be hit by a car); you could never drive over a bridge (after all, it might collapse); you could never get married (after all, it might end in disaster), etc. If anybody really acted in this way he would soon end up in a mental institution. (Harsanyi 1975, p. 595)

Presumably, Harsanyi does not mean to entirely disregard the possibility of that worst outcome, but rather proposes that it be discounted for its low probability. Some do in fact recommend that low-probability risks be ignored entirely rather than being discounted in this way, but as Shrader-Frechette (1985) has shown, this conflicts with the terms of risk analysis itself, particularly with low probability but high-cost risks like nuclear meltdowns. Harsanyi implies that the expected value of the Chicago job is higher than the New York job even after subtracting the discounted disvalue of your being killed in a plane crash in invoking expected utility, although he never specifically addresses probabilities or discounting. So long as probabilities can be estimated in this way, however and so long as agents are able to attach a finite disvalue to their being killed,[2] risky individual choices are at least sometimes warranted. In such cases, Harsanyi's point begs the question but is reasonable: in so far as we understand rationality in terms of expected utility maximization, the rational choice would be to maximize expected utility, not to minimize risk or avoid worst cases. Your choice to take the Chicago job would be the rational one, no matter whether you arrive there safely, since rationality lies in the prospective estimate of the respective values of various outcomes, not in the retrospective assessment of how things in fact turn out. Risk-taking, in this sense, involves *ex ante* acceptance of downside risks in light of their upside payoffs, and is sometimes warranted despite risks of very bad outcomes.

But this sort of analysis applies only to a limited range of decisions, excluding the social distribution of resources that is the subject of Rawls's principle, since maximin involves actual bad outcomes for someone and not the merely possible worst cases that he alleges. Individuals might validly rely upon expected value in making risky decisions that affect only themselves, as in Harsanyi's example, but cannot use it when choosing whether to impose risk upon others. In individual cases, persons accept risks when they choose the prospect of better outcomes despite the possibility of worse ones, and so harm only themselves if the bad outcome obtains. Even in such individual cases, persons tend not to employ the expected value approach of standard risk analysis, with most preferring to avoid certain losses by risking greater losses (for example, preferring a 50% chance of losing $3 to a certain loss of $1) but preferring certain gains over chances for greater ones (for example, preferring $1 over a 50% chance at $3). Risk tolerance and aversion varies across persons and decisions, and typically involves personal dispositions and contexts rather than quantitative expected value analysis (Jarvis Thomson 1986). Rather than presuming consent to risk acceptance when expected value analysis declares it rational for persons to take a given risk, an autonomy-focused approach to risk would give persons the opportunity to make informed decisions about the risks they will take. If you take the Chicago job, then you accept the risks of being killed in exchange for the upside benefits. If someone else puts you on that plane without your consent, based perhaps on Harsanyi's analysis, then you have not accepted that risk, and you can object to the risk imposition even if your plane arrives safely.

Personal risk-taking may sometimes be imprudent, but it is never wrong or unjust, at least where it involves the informed consent of rational agents. Societal risk-taking, by contrast, often involves imposed rather than freely-accepted risk, as Shrader-Frechette notes. 'In the individual case', she writes, 'the risk is freely chosen by one person, but in the societal instance, it is often involuntarily imposed on a group, without consent' (Shrader-Frechette 1988, p. 506). While societal risk could in principle be democratically accepted by an entire community, several considerations undermine the legitimacy of a popular plebiscite on the kinds of risk involved in nuclear energy expansion or climate change. First, in a society of any significant size, the likelihood of unanimous support for either option is extremely small, and majority rule decisions in cases involving risk allow for the imposition of risk upon a minority for the benefit of the majority. To avoid objections about risk imposition, all must freely accept that risk. Where a society is required to choose between two alternative risks, as with the climate–nuclear dilemma, a consensus decision rule for nuclear expansion would surely result in heightened climate-related risks, absent the requisite consensus on behalf of rejecting the *status quo* option. Moreover, the relevant polity depends on the scope of the risks involved, and differs between the climate and nuclear cases. Since climate change is expected to adversely affect residents of developing countries and future generations much more than current Americans, any plebiscite on accepting climate-related risks would have to include non-residents and future persons (Vanderheiden 2008), else it risks objectionably imposing risks onto others for the benefit of those allowed to control that imposition. Those most affected by the nuclear decision include residents whose utility rates or taxes stand to be increased by the decision to subsidize nuclear over fossil fuel-based power, along with those whose proximity to nuclear facilities renders them vulnerable to nuclear accidents. No polity constituted around the affectedness principle (Goodin 2007) can validly choose between these two risk sets, since those asked to accept one set would not be the same as those asked to accept the other.

To illustrate the difficulties involved in making societal risk decisions, Shrader-Frechette considers whether to disband or maintain a country's nuclear energy program, where there exists a low-probability but high-cost outcome in which nuclear reactor operators commit serious errors that result in a meltdown akin to that at Three Mile Island. As some nuclear plants are currently online, the decision to mothball them from safety concerns would result in substantial foregone energy production, but this would prevent the worst-case outcome. Maintaining rather than disbanding the current nuclear program results in either the best or worst outcome, depending on whether or not reactor operators make serious errors. The decision set is therefore as presented in Table 2.

As before, the maximin rule counsels that the nuclear program be disbanded in order to avoid the worst possible outcome, but it remains unclear which of the two options would yield maximum expected utility. Shrader-Frechette's point here is that the Bayesian decision depends upon how

Table 2. Nuclear program decision set.

	Nuclear reactor operators make serious errors	Nuclear reactor operators do not make serious errors
Nuclear program maintained	Serious accident in which many people die	Higher energy production and lower energy costs
Nuclear program disbanded	Accident avoided, but financial loss from lower energy supply	Financial loss from lower energy supply

the probability of reactor operator mistakes is calculated, but a more fundamental objection to the use of either standard risk analysis or democratically accepted risk is suggested by this case. Using standard risk analysis, the potential costs of a nuclear accident are discounted by their probability and then compared against the costs associated with disbanding the nuclear program. Depending upon that probability, maintaining the program may yield higher expected value, but through an objectionable displacement of risks. The benefits of maintaining the nuclear program are widely distributed, through lower energy costs (in her example), but the potential costs are narrowly concentrated among those residing near nuclear facilities. Even if the overall expected benefits exceed overall expected costs, the opposite is likely to be true for those most vulnerable to nuclear accidents, whose lives would be risked so that others could save money on their power bills. This hardly seems fair to them, but this unfairness cannot be captured by standard forms of risk analysis, which take no account of the distribution of risks across a population. Likewise, if the decision was made by majority rule rather than authoritatively imposed by a risk-minimizing state guided by Bayesian risk analysis, the same displacement of risk onto those most vulnerable could occur, raising the same objections.

The moral illegitimacy of risking someone else's welfare for benefits to oneself can be illustrated by another thought experiment: suppose that I make a wager that will pay each of us $1000 if we win but will cost you your life if we lose. Here, risk's upside benefits are equally shared but its potential costs are concentrated on you. The bet is a good one for me, since I would be insulated from its downside risks but not its upside rewards, but you would look at it (and probably also me, for wagering your life like this) with reasonable suspicion. It would be irrational for you to agree to that payoff structure, but it would be worse if I was to make this wager on your behalf without your consent. In the case above, it is difficult to imagine how anyone could rationally accept the risks of being killed in a reactor meltdown, no matter how improbable this possibility, for some marginal savings off their monthly utility bill. At some low probability, however, the tradeoff would be rational to accept, in expected utility terms. There is nothing unjust about persons taking irrational risks in order to potentially gain upside rewards, but its imposition without the consent of those whose lives are jeopardized by it would still be objectionable even if their consent would be rational. Risk-taking is a cornerstone of much of modern life, and Harsanyi is justified in ridiculing the extremely risk-averse as excessively and even viciously timid. Refusing to accept even minute risks makes extremely risk-averse persons a tremendous burden to others, who will be forced to incur risks on their behalf. However, the voluntary acceptance of risk differs from its imposition, even with the same payoff structure, and the concern here lies with the circumstances under which risk can be imposed upon some people in exchange for benefits that accrue to others.

In many cases of societal risk, it is untenable to require the prior informed and unanimous consent of all those subjected to downside risk, granting all potentially affected persons a veto over risky decisions. The imposition of risk on others is sometimes justified, where consent is impossible or impractical to obtain, where collective benefits require that all are subjected to some risk if any are, where the risky decision equitably allocates the costs and benefits of risk, and where the expected benefits outweigh expected costs for each. Here, risk is viewed as one kind of cost that is sometimes necessary for procuring important social benefits, but which must be equitably assigned in view of those benefits. Displacing risks onto some so that others may benefit in this sense constitutes a distributive injustice, but justly distributed risks and benefits may in some cases be assigned without the express consent of those affected by them. My 401K manager can legitimately purchase a volatile stock at some low price without every shareholder giving their consent in advance, even though investors are thereby placed at some financial risk as a consequence, since the potential costs and benefits of this decision are equitably distributed among investors. Those with more shares stand to gain or lose in proportion to their holdings. But that manager could not place all investors at greater risk in exchange for benefits that accrue only to some, as this would amount to an unjust transfer of costs in one direction and benefits in the other. Trustees, like fund managers, typically take such calculated risks on behalf of their clients, and it is expected that they do so, although their judgment may reasonably be called into question later if risky decisions repeatedly go wrong. Governments act as trustees on behalf of their citizens, and must impose some risks in order to provide collective goods. Where this risk imposition appears imprudent or inequitable in its exchange of upside benefits for downside risks, its legitimacy as a trustee of the public comes under scrutiny, and rightly so.

Polities can accept risk through democratic processes, which are analogous to informed consent in individuals, and as Shrader-Frechette (1988, p. 506) notes: 'democratic *process* is probably *more important* in cases of societal risk under uncertainty'. But majority-rule processes that subject minorities to risk of serious harm in exchange for benefits that accrue primarily to the majority, when such risks would be irrational for that minority to accept, cannot be justified in this way. Trusteeship implies that decisions made on behalf of others without their consent are expected to benefit those others, and *could* be the subject of their consent even if they are not in fact. Imposing risks upon others that do not meet this criterion instead involves *risk displacement*, violating the rights of those placed at unjustified risk in a way that *ex ante* compensation cannot fully correct (McKerlie 1986). Given the unavoidability of some societal risk-taking, the question must be: under what circumstances can some imposition of risk be justified? Since the 'nuclear option' involves exchanging one set of risks for another, and thus also placing a different set of subjects at risk, criteria for acceptable societal risk-taking must be able to meaningfully compare alterative risk sets, with their distributed costs and benefits, and prescribe compensatory measures for those made worse off by the best option.

Commensurable risks?

We can now return to evaluating the decision to expand nuclear power programs in light of imperatives to mitigate anthropogenic climate change. Here, the potential costs and benefits of two separate but related categories of risk tradeoff, although the probabilities and magnitudes of each kind of risk are shrouded in uncertainty. As noted above, the United States would increase its greenhouse emissions by 6–7% and global emissions by 2%, holding other variables constant, if it was to decommission all of its currently-operating nuclear plants, increasing one kind of risk while decreasing another. Likewise, a significantly expanded US nuclear energy program could reduce national and global emissions by a similar amount, reducing climate risks but at the expense of nuclear ones. While these marginal changes correspond with non-trivial increases and reductions in climate-related risk, the US 'nuclear option' falls well short of what scientists estimate will be necessary in order to avoid 'dangerous anthropogenic interference' with the earth's climate system, and it is impossible to know what specific hazards this would avoid, but it should reduce climate-related risks at the expense of higher nuclear-related ones. Unlike the above analysis, in which low-probability but high cost outcomes were compared against certain intermediate ones, the tradeoff involves low-probability but high cost outcomes becoming slightly higher-probability (with nuclear expansion) in order to marginally reduce high-probability but intermediate cost outcomes. The decision looks something like that presented in Table 3.

Here, the top right sextant is plainly the best-case scenario, and the middle left one is the worst. But we cannot meaningfully compare the three options on the basis of either sextant on its own, without knowing how our choices affect the probability of an accident occurring. Comparing both expansion and disbandment of the nuclear program against the *status quo*, we need to know how rising expected climate benefits affect rising accident risks and how reducing accident risks increases those from climate. If we could be certain to

Table 3. Risk tradeoff decision.

	Nuclear accident occurs with existing nuclear program	No nuclear-related harm
Expand nuclear program	Maximum climate benefits (but climate-related harm only marginally diminished), but nuclear catastrophe outweighs	Maximum climate benefits, and no harm from raised risk of nuclear catastrophe
Maintain nuclear program	Foregone climate benefits, and catastrophic nuclear accident occurs anyway	Higher climate risks, with no corresponding safety benefit
Disband nuclear program	Averted catastrophic harm, but higher climate-related harm	No catastrophic harm, but none averted to justify the opportunity costs for climate

remain in the right-hand column – that no harm would result from our nuclear program, should we maintain or expand it – better results come from being higher in the column, but moving higher also raises the probability of moving into the left-hand column, in which case we would prefer to be lower. Given uncertainty about this tradeoff between two risky courses of action, how do we compare our three options?

Analytic decision theories are stumped by tradeoffs of this sort. There is no dominant game theory option in this trilemma, which differs from prisoners' dilemmas in that outcomes depend on a chance element rather than decisions of others. The worst outcome above results from maintaining current programs when an accident occurs, but maintaining is superior to disbanding if the accident does not occur, although it increases the probability of the accident occurring. While expanding the program is superior to either of the other options whether or not accidents occur, it also increases the likelihood of such accidents, compared with maintaining or disbanding the program. One might instead employ a Bayesian risk analysis, but absent more robust probability estimates for accidents occurring at various levels of nuclear energy use, it would be impossible to reliably estimate the expected value of each option. Moreover, options are linear rather than threefold, since expansion or reduction from current levels can be by one plant or several, and expected values for all possible levels of nuclear power deployment would need to be calculated in order to be meaningfully compared. The optimum level of nuclear power production comes just below the threshold at which an accident occurs – at which point it would have been better to use just less – but this threshold cannot be calculated in advance, and may not even be a function of overall use rates. Decision theory must be prospective, rendering it useless where the primary variable needed to rank options cannot be known in advance and its probability in each option cannot be accurately estimated. In short, game theory and quantitative risk analysis both fail to resolve the climate–nuclear dilemma, prescribing an appropriate role for nuclear power in the decarbonizing imperatives of climate change mitigation policies.

Procedural democratic theories fare no better. As suggested above, risky decisions must take account of public preferences where possible. As J.E.J. Altham notes, persons are willing to accept much higher levels of risk when given the choice to do so, as opposed to when such risks are imposed, making democracy a means of managing risk as well as a procedure for choosing among risky options. He writes: 'The risk of smoking twenty cigarettes a day is reckoned to be pretty high. A risk of similar magnitude to the general public from an industrial process, even a very beneficial one, would be regarded as quite intolerable' (Altham 1984, p. 29). Absent full consensus by all those who stand to be affected by the dual risks of nuclear energy and climate change – a consensus that depends on the participation of future persons in decision-making processes and which would necessarily oppose the rational interests of those on whom greater risk is imposed than they receive in upside benefits – majority rule decision rules invite charges of unfairness and illegitimately imposed risk. Indeed, rights against imposed risk are regarded as necessary protections against majority tyranny, but raise problems of their own in cases like this one where some risk is unavoidable, since inequitably imposed risk can in principle be corrected through compensation schemes but rights violations cannot (McCarthy 1996, Zimmerman 2006). As Shrader-Frechette notes of the effort to address fundamentally democratic questions through analytic decision theories rather than political contestation:

> All risk questions are ultimately philosophical questions. To attempt to reduce them to purely scientific issues ... is to ignore the value dimension of policy analysis and to disenfranchise the public who, in a democracy, ought to control that policy. (1985, p. 442)

But in this case, neither democratic nor analytic resolution to the climate–nuclear dilemma appears possible, given inherent limits of each process.

Conclusion: seeking traction in a third way

One strategy for resolving alleged dilemmas in which both horns offer incommensurably bad options is to show that there is actually a third option that is clearly superior to either of the other two. Indeed, this has been the strategy of those opposing the nuclear option as a response to the predicted hazards of climate change, who point to potential benefits of conservation and the combination of safety and efficiency available through expanded deployment of renewable energy technologies, including solar, wind, hydroelectric and geothermal power (World Information Services on Energy 2005).[3] By this analysis, the supposed choice between accepting the risks associated with expanded reliance upon nuclear power or intensified climate change is a false one, given that greenhouse emissions can be reduced by the same amount through far less risky electrical generation technologies and conservation options. Such proposals are obviously appealing in that they avoid the dilemma of apparently incommensurable risks discussed above by offering comparable but clearly preferable options. If the data concerning the relative safety and cost-effectiveness of renewable energy technologies compared with nuclear power are accurate, they obviously present a compelling policy alternative to either of the unattractive options posed against each other above. No doubt, these renewable energy options can go a long way toward decarbonizing the energy economy, and they may together someday replace fossil fuels entirely in providing an electricity infrastructure. In the meantime, existing nuclear facilities are nearing the expiration of their operating licenses, and some argue for their replacement with new nuclear facilities rather than with the coal-fired plants that would otherwise be brought online to 'bridge the gap' between energy supply and demand, further entrenching fossil fuels in the energy infrastructure for decades to come. Given the urgent imperative to start decarbonizing now, what can be said for or against the claim that nuclear power must remain an energy source into the intermediate future, until such time as renewable sources are able to meet the world's full energy needs?

While a full accounting of the distributive implications of climate change and nuclear energy is beyond the scope of this paper, a tentative response to this challenge can be ventured by revisiting Beck's notion that the distribution of risk rather than scarce resources is now the most fundamental role of the state and the most basic task of justice: when our demand for energy forces us to choose between placing some at risk of being killed in a nuclear accident or devastated by climate change, we must consider whether the activities that create this demand benefit those whose welfare has been offered in collateral for the wager in which we benefit ourselves through the imposition of risks onto others. Even if it is not certain that they will be harmed, the fact that we subject others to substantially higher risks of being harmed requires some justification. Do these same activities also make them better off in some tangible way? Is the circumstance under which they are placed at greater risk of harm something to which they would give their informed consent, in that they stand to benefit by the upside rewards of a risky activity as well as the downside risks? Or are we merely displacing the costs of our affluent lifestyles onto those made vulnerable to nuclear accidents or climate change, whether in the near or more distant future? If the latter, we must think seriously about the fair distribution of risks and rewards, and the distributive injustice of insulating ourselves from the risks while those made vulnerable to it are largely insulated from its rewards. And we must act accordingly.

Resolving the nuclear–climate dilemma by finding a third alternative that avoids the hard choice between its two unpalatable horns may be policy savvy, and the ecological modernization discourse on which it rests offers an attractive narrative of a relatively painless decarbonization path. Certainly, 'clean energy' technologies should be developed and deployed in replacement of the fossil fuel-based plants that the planet cannot much longer tolerate, and we must not pretend that there would not be a climate-related cost to the decision to disband existing nuclear power facilities, or an opportunity cost to climate in not expanding them. This cost must be borne by those who benefit by the activities that make it necessary, as climate-related costs are unlikely to be. For this reason, we cannot merely displace such risks through climate change or expanded nuclear power, for the downside costs of these options are borne primarily by their non-beneficiaries. If we significantly injure or kill those who are made more vulnerable as the result of risks that we impose upon them as the result of choices from which we primarily benefit, then we cannot adequately compensate them for their injury. Modernization, as Beck argues, begat the risk society in which we live and to which we contribute risk, so it cannot also be expected to fully remedy that situation. Ultimately, greater attention to the distribution of risks and the rewards that attach to them ought to persuade us not only to avoid the risks of severe and irreversible harm where possible, but also to assign far more of the risks to ourselves rather than others in cases where we are also the primary beneficiaries of risky activities, so that we may displace fewer onto others. We should, in other words, strive to live more sustainably in order to act justly toward others, given the mutually reinforcing nature these dual imperatives.

Notes

1. As the Union of Concerned Scientists (2007, p. 29) notes: 'the Price-Anderson liability limit therefore serves as a disincentive for industry to develop and use additional safety features, or to adopt reactor designs that are safer but more expensive'.
2. If, on the other hand, one attaches infinite disvalue to being killed, even a very low probability of that outcome makes it irrational, since a discounted infinity remains infinite. Quantitative risk assessment cannot accommodate infinite value, and so is easier to use in assessing risks to others than for risks to self.
3. See, for example, World Information Services on Energy (2005).

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