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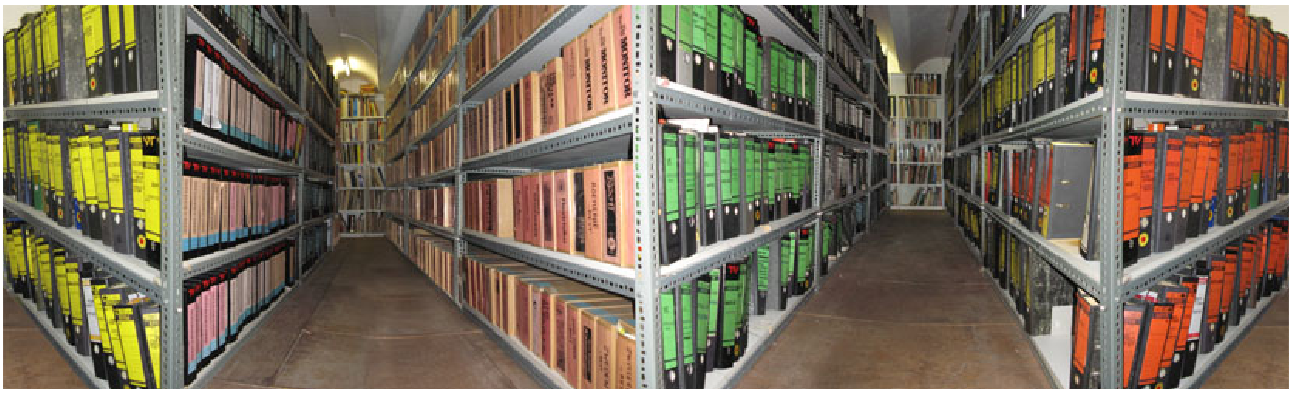

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Viewpoint

The ethics of nuclear power: Social experiments, intergenerational justice, and emotions

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ABSTRACT

In this paper we argue that traditional approaches to risk assessment should be supplemented by an explicit discussion of the moral acceptability of nuclear technology and the risks it poses. The introduction of nuclear energy in society should be seen as an ongoing social experiment, whose (moral) acceptability should continuously be addressed. Given the long-term risks of nuclear energy, intergenerational justice should be explicitly included in such an analysis. This will also have implications for nuclear power policies. Furthermore, emotions such as sympathy and feelings of responsibility can provide moral insights; they should be taken seriously in the debate about nuclear energy rather than being dismissed as irrational distractions as is currently the case. These proposed reforms would help society to move beyond the usual stalemate in the debate about nuclear power.

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1. Introduction

The Fukushima accident has brought nuclear power to the forefront of political controversy again. This controversy is particularly hard to resolve due to four specific characteristics of the risks of nuclear energy: (i) a nuclear accident has a low probability but potentially very large consequences; (ii) nuclear risk assessments are thwarted by high levels of uncertainty and even ignorance; (iii) nuclear waste remains radiotoxic for several hundred thousands of years; and (iv) nuclear technology gives rise to intense emotions by both proponents and opponents. As a consequence, traditional approaches to risk assessment no longer suffice to deal adequately with the risks of nuclear power and should be supplemented by an explicit discussion of the moral acceptability of the risks of nuclear technology.

In Section 2 of this paper, we focus on the (technical) inadequacy of current Probabilistic Risk Assessments in dealing with nuclear risk. We propose to conceive the introduction of nuclear energy in society as an ongoing social experiment, which raises a number of ethical issues. One such important issue that conventional risk approaches virtually neglect is that of intergenerational justice. In Section 3, we elaborate on what it means to contemplate justice to posterity in nuclear power production and its tangible implications for policy-making. Section 4 focuses on the role of emotions in the nuclear debate and the insights they provide in the evaluative aspects of nuclear risks. We conclude by arguing that explicitly addressing these issues (i.e. ethical implications of nuclear energy as a social experiment, intergenerational justice and moral emotions) will lead to more fruitful debates about nuclear energy, as all important ethical considerations will get sufficient attention.

2. Nuclear technology as a social experiment

Risk assessment is a major element of the conventional approach to nuclear power. Risk estimates are usually based on Probabilistic Risk Assessment (PRA) (Keller and Modarres, 2005). In the initial days of nuclear power, nuclear risks could neither be based on a theory of reactor operation nor on historical accident data. To deal with this problem, Rasmussen introduced the approach of PRA in which risks are estimated on the basis of identifying the events that could lead to an accident and assigning probabilities to those events (NRC, 1975).

Whilst PRA is a useful instrument to identify and eliminate safety weaknesses in reactor design, the estimated accident probabilities have become increasingly important in policy-making. A major accident in a reactor can occur as a result of damage to the reactor core, the probability of which is expressed in terms of a core damage frequency (CDF) per year of reactor operation, or reactor year (RY). Rasmussen's report estimated a CDF for Generation II reactors to be between 2.6×10^{-5} and 5×10^{-5}, indicating an accident probability of one in every 20,000 to 40,000 RY.[1] Based on approximately 500

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[1] These probabilities refer to the CDF in a Boiling Water Reactor and a Pressurized Water Reactor (NRC, 1975). Together they comprise Generation II reactors that are the majority of currently operable reactors.

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nuclear power plants operational worldwide,[2] this would result in one accident in every 40 to 80 years. The International Atomic Energy Agency (IAEA, 2001, p. 73), states that future power plants should have a CDF of less than 1 in 100,000 RY (for current power plants it is one in 10,000 RY).

Historical data, however, suggest a considerably higher core damage frequency of once in every 1300 RY. In this estimation, eleven severe accidents have been taken into account. Indeed, this estimation depends on what exactly constitutes *severe core damage* and "experts differ regarding the level of core or fuel damage that needs to occur before the event should be counted in assessing CDF" (Cochran and McKinzie, 2011, p. 13). Even when we reduce that number to the uncontroversial four severe core damages (referring to one reactor in Chernobyl and three reactors in Fukushima), the historic results suggest one accident in every 3600 RY.[3]

Whilst the number of these accidents is too low to draw statistically relevant conclusions, we can safely assume that there is a serious discrepancy between historical data and the estimated CDFs. It is therefore questionable whether Probabilistic Risk Assessment can adequately deal with uncertainties. In some cases, PRA estimations cannot be substantiated by empirical data, since disaster scenarios such as earthquakes or tsunamis cannot be tested in the laboratory. Moreover, disaster scenarios that are unknown cannot be taken into account in PRA estimations. A final point is that certain risks depend on the behavior of human beings, which might be hard to predict, especially in the case of the long-term risks of nuclear waste. For all these reasons, the employment of nuclear energy technology retains an experimental nature even after its implementation in society. It is a social experiment (van de Poel, 2009, 2011).

Social experiments are different from standard experiments in at least three respects. Firstly, they take place outside the lab and involve more and other human subjects than standard experiments, in particular users and bystanders. Secondly, they are not always explicitly carried out or recognized as experiments, so that data gathering or monitoring is sometimes absent. Thirdly, they are less controllable, which makes it more difficult to manage experimental conditions and to avoid hazards. Social experiments may be difficult to terminate or they may have irreversible consequences. The mentioned characteristics of social experiments raise the question about under what conditions social experiments with nuclear energy are acceptable, and if they are acceptable at all (van de Poel, 2009, 2011). The ethical requirements that have been formulated for experiments involving human subjects in laboratory conditions can be a starting point here, i.e. respect for persons, beneficence and justice (Ryan et al., 1978). However, to apply these ethical requirements to social experiments, they have to be reformulated and further specified (van de Poel, 2011). Table 1 provides a more detailed list of conditions one might want to pose (based on van de Poel, 2011). These conditions are based on the mentioned moral principles of respects for persons (9,10,11), beneficence (1,3,7,8), and justice (12,13), and considerations pertaining to the potential role of experiments in the introduction and management of new technology in society (2,4,5,6).

Table 1
Possible conditions for responsible experimentation (van de Poel, 2011).

1. Absence of other reasonable means for gaining knowledge about hazards
2. Monitoring
3. Possibility to stop the experiment
4. Consciously scaling up
5. Flexible set-up
6. Avoid experiments that undermine resilience of receiving 'system'
7. Containment of hazards as far as reasonably possible
8. Reasonable to expect social benefits from the experiment
9. Experimental subjects are informed
10. Approved by democratically legitimized bodies
11. Experimental subjects can influence the setup, carrying out and stopping of the experiment
12. Vulnerable experimental subjects are either not subject to the experiment or are additionally protected
13. A fair distribution of potential hazards and benefits

This list draws attention to at least three aspects of responsible experimentation. One aspect is that the experiments should be set up in an adequate way, and this requires competent engineering and management of technology (conditions 1–7). The second aspect is that responsible experimentation requires a form of democratic decision-making and legitimation, and a reasonable expectation that the experiment might eventually contribute to human well-being (conditions 8–11). In such democratic debates, emotions have an appropriate role to play as we will argue in Section 4. The third aspect refers to considerations of distributive justice (conditions 12 and 13). This third aspect directly connects to the importance of considerations of intergenerational justice that we will discuss in the following section.

3. Intergenerational justice

Discussions on the acceptability of nuclear power as a social experiment should include considerations of intergenerational justice. Together with fossil fuel combustion that causes climate change, nuclear power is probably among the clearest examples of technologies with risks far beyond generational borders (Taebi, 2012). These intergenerational risks emanate from two factors. Firstly, like fossil fuel, uranium as the primary fuel of nuclear power is a finite resource; our consumption today limits the access of posterity to these energy resources. The second intergenerational aspect is again one that fossil fuel and nuclear power share, namely the change in the intergenerational distribution pattern of burdens and benefits. Arguably, the benefits of nuclear power production are mainly for the present generations, while some burdens such as accidents in a reactor are for the present people as well. What is morally troublesome from an intergenerational perspective is that some burdens in terms of the remaining of long-living radiotoxic waste will be transferred into the future. While nuclear power production has also some benefits for future generations in terms of the continuation of well-being, the perpetuated burdens over the hundred thousands of years do not seem to be justified with the created future benefits. What exacerbates this moral problem is the asymmetry of power between us and generations yet to come, which means that we are in a position to impose costs on them (Gardiner, 2003). These intergenerational justice problems create certain moral obligations for contemporaries (Shrader-Frechette, 2000; Taebi, 2011). Following egalitarian principles of justice to the effect that location in space or time could never justify different treatments of people (Barry, 1999), one can argue that the interests of future generations should be included in today's decision-making. These moral obligations have tangible implications for policy-making, in the choice for and between ways to generate nuclear power.

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[2] In May 2012, there were 433 nuclear power plants operational worldwide (WNA, 2012).

[3] Until 2011, there have been 593 nuclear power reactors operational worldwide; together they have operated approximately 14,400 reactor-years (Cochran and McKinzie, 2011). Based on 11 severe accidents, a core-melt accident is about one in 1300 reactor. years [14,400/11=1309] (Cochran, 2011). With 4 severe accidents, the historical frequency of a core melt accident is once in 3600 reactor years [14,400/4=3600].

Before moving on to specify the implications of these temporal obligations for choices that policy-makers need to deal with, two remarks are in order. Firstly, intergenerational justice is sometimes taken to refer to different things. Proponents of nuclear energy for instance argue that from an intergenerational justice point of view nuclear power is justified since it can deal with climate change (e.g. Forsberg, 2009), while the opponents find nuclear power irresponsible because of its intergenerational burdens of nuclear waste (e.g. Shrader-Frechette, 2011). Dealing with this issue requires answering the more fundamental questions of which 'evil' is more important to be avoided and why. Secondly, there is another contention between the proponents and opponents of underground disposal of nuclear waste. Some scholars argue that from an intergenerational point of view we should dispose off the waste underground in order to avoid burdens for the next generation (e.g. Okrent, 1999), while other scholars argue that the long-term uncertainties should stop us from geologic waste disposal (e.g. Shrader-Frechette, 1993). This contention is about how we rank the interests of different future generations, particularly those of the immediately following generations and those in the far future.[4]

Nuclear power is currently produced in two ways, the open or the closed fuel cycle. In the former method, also known as the 'once-through', nuclear fuel is irradiated once in the reactor, and the remaining waste should be isolated from the biosphere for a very long time; for instance U.S. legislation requires isolation for one million years (EPA, 2008). In the closed cycle method, spent fuel is recycled (or reprocessed) resulting in lower waste life-time and reusable materials, namely uranium and plutonium. Reprocessing is a very costly chemical process only available in a handful of countries. While it reduces the volume of the troublesome waste and its life-time to about ten thousands of years, it produces other types of waste with shorter life-times. More importantly, reprocessing entails separating uranium and plutonium. The main purpose of this is to reinsert these materials in the fuel cycle. However, separated plutonium has serious proliferation risks. The world's first reprocessing plant has been built during WWII in the US with the main purpose to recover plutonium for the 'Fat Man', the bomb that was dropped on Nagasaki in 1945.

Technological and governance solutions have been presented to make the closed cycle less proliferation sensitive, while enjoying its benefits. Technological methods have been proposed to keep uranium and plutonium mixed in the reprocessing, since only the pure plutonium could be used as an ingredient for the nuclear bomb. This method has not been successful because pure plutonium could still be separated out from this mixture (Von Hippel, 2007, p. 4). Global governance proposals have been made particularly by the United States, the most notable of which is the 'Global Nuclear Energy Partnership' (GNEP), in which weapon states and Japan[5] were expected to provide reprocessing services for other states. This proposal "backfired in stimulating a revival of interest in France in exporting reprocessing technology and in South Korea in acquiring its own national reprocessing capabilities" (Von Hippel, 2007, p. 4).

To sum up, the closed fuel cycle creates short-term proliferation risks, economic burdens and additional health and safety risks for both the general public and the workers at the nuclear facilities.[6] But it seems to be more preferable for future generations because it reduces the long-term burdens of the waste. This raises the fundamental question as to what extent we can accept additional risks to the present generation, in order to diminish risks for future generation (Taebi and Kloosterman, 2008). An answer to this question has relevant implications for the future of nuclear fuel cycles. For example, there is a new technology, known as Partitioning and Transmutation (P&T), which allows a substantial reduction of the waste life-time by multiple reprocessing and eliminating long-lived isotopes in a *fast reactor* or *accelerator driven systems* (ADS). These technologies are still in their experimental infancy and they require at least four decades of development and substantial investments and they create even more safety and security burdens for present generations (IAEA, 2004; NEA-OECD, 2002). A serious challenge is to make the P&T proliferation resistant, either with technological or governance solutions (Cochran et al., 2010).

In conclusion, when assessing the acceptability of nuclear power, we need to distinguish between different production and waste management methods and map their consequences for present and future generations. Whether a technology such as P&T is acceptable could be addressed in terms of the more fundamental question of to what extent justice to future generations requires accepting additional burdens for the present generations (Taebi, 2011).

4. Moral emotions and nuclear risks

The previously discussed aspects of the risks of nuclear power have given rise to heated emotional debates (Slovic, 2010a). Policy makers typically respond to these emotions in two ways: either they ignore the emotions of the public or they take them as a reason to prohibit or restrict nuclear technology. We can call these responses the 'technocratic pitfall' and the 'populist pitfall' (Roeser, 2011b). In both cases, a genuine debate about nuclear energy is avoided, as the public is supposedly too emotional and hence incapable of engaging in a rational debate. Moreover, risk is not only a quantitative, factual notion but it also involves values (Hansson, 2004). The facts and the values are both often highly contested and constructed differently by different stakeholders and cultural groups (Krimsky and Golding, 1992; Slovic, 2000; Kahan, 2012). Because of these emotions and controversial values, some authors argue that we should only use quantitative approaches to risk such as cost-benefit analysis rather than involving the public (Sunstein, 2005).

However, risk and safety are inherently normative notions or so-called 'thick concepts': they have factual and ethical aspects at the same time (Möller, 2012). As argued in Sections 2 and 3, the risks of nuclear energy have ethical aspects such as respect for persons, beneficence, and intergenerational justice. Moral philosophers emphasize that one cannot simply derive values from facts (Hume, 1975a, [1739–1740]; Moore, 1988 [1903]). The quantitative, scientific aspects of risk are studied by empirical disciplines, but the evaluative aspects of risk require ethical reflection. Risky technologies can affect the wellbeing of people. Determining how to balance the value of human life, long term illnesses and environmental effects and how to distribute risks and benefits cannot be done by purely quantitative methods. It also involves ethical reflection that goes beyond conventional approaches to risk such as cost-benefit analysis (Shrader-Frechette, 2002; Asveld and Roeser, 2009).

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[4] For an elaborated discussion of how policy-making deals with this issue, see Taebi (2012).

[5] Japan is the only non-weapon state that engages in commercial reprocessing for energy purposes.

[6] Protecting workers against their occupational risk deserves serious attention (Hansson, 1998), particularly for radiation workers who are continuously exposed to ionizing radiation (ICRP, 1997); serious health impacts could arise from the accumulation of radiation.

Empirical research shows that laypeople have a broader understanding of risks than experts, which involves ethical considerations (Slovic, 2000), the same ones that are also emphasized by philosophers (Asveld and Roeser, 2009). This might be due to the fact that emotions play an important role in the risk perceptions of the public. Neuropsychological research shows that emotions are actually necessary in order to make practical and moral judgments (Damasio, 1994). Emotion scholars argue that the traditional dichotomy between reason and emotions is mistaken. Emotions are a form of cognition and knowledge, specifically when it comes to value judgments (Solomon, 1993; Nussbaum, 2001). Emotions are appraisals (Frijda, 1987), they show us what is valuable and what matters. They are more powerful in directing our attention to moral issues than purely cognitive states (Roeser, 2011a). According to for example sentimentalist (Hume, 1975b [1748–1752]; Blackburn, 1998) and virtue ethical approaches (Aristotle, 2002; Sherman, 1989) to ethics, emotions are necessary for ethical reflection. So, rather than being an obstacle to a genuine debate about nuclear energy, emotions might be the key to a debate that explicitly addresses ethical issues such as intergenerational justice that are left out of conventional, technocratic approaches to nuclear energy (Kahan, 2008; Roeser, 2010).

Purely quantitative approaches to risk might actually blur rather than clarify ethical issues. Paul Slovic has conducted studies that show that people get ‘numbed by numbers’. For example, in the case of donating to charities, people are prone to give more money based on the narrative about a single child than on statistical information that presents the full scale of a problem. One would expect a linear relation between the number of victims and our capacity to care and our willingness to help, but the opposite turns out to be the case (Slovic, 2010b). This work by Slovic shows the limitations of our capacity for compassion, but it also shows the complete failure of our purely rational capacities to respond appropriately to atrocities. This can be overcome by presenting information in a way that appeals to emotions, such as feelings of justice and sympathy for future generations, for example by appealing to understandable, gripping narratives (Roeser, 2012). As Nussbaum (2001) has argued, art and narratives can expand our compassion from those that are close by to more distant others. Thus, to the extent that concerns and care for future generations already play a role in debates about nuclear energy, this is justified and should even be enhanced.

Feelings of responsibility for our descendants seem to play an important role in the argumentation of both nuclear proponents and opponents. Whilst the former will refer to the problem of climate change, presenting nuclear power at least as a temporary solution for bridging the gap towards renewable energy resources, the latter will contemplate its temporal responsibility as avoiding the perpetual burdens of nuclear waste into the distant future. Next to care about future generations, there are other emotions of proponents and opponents of nuclear energy. The emotions of opponents of nuclear energy include fear of a catastrophic event and indignation at involuntary risk impositions by social experiments. The emotions of proponents include curiosity and enthusiasm for the possibilities and benefits that nuclear energy might offer compared to, for example, coal energy. All of these emotions reveal important evaluative aspects of nuclear energy and should be taken seriously in the debate. By addressing opposed emotions as starting points of debates rather than neglecting them or taking them as endpoints of debates as is currently often the case, the underlying ethical concerns can be made explicit and discussed.

There are several possible ways of incorporating risk emotions in decision making about nuclear energy. One way would be to take emotions as the starting point in debates about nuclear energy, by evaluating the moral reasons underlying the emotions and critically reflecting about them. Another way would be to use narratives, film and literature to make people emotionally aware of the impact of different sources of energy and their concomitant risks on people’s lives. Yet another way would be to let experts and laypeople co-develop scenarios for designing morally desirable nuclear reactors. In all these approaches, the different moral considerations and trade offs mentioned in Sections 2 and 3 should be made explicit, based on emotional concerns. Explicitly focusing on ethical and emotional concerns brings experts and laypeople on common ground, as these are capacities that all human beings share. This could help overcome the common opposition between experts and laypeople in debates about nuclear energy and contribute to constructive solutions to the pressing ethical issues involved in nuclear energy.

5. Conclusion: towards a more nuanced debate about nuclear energy

The previously discussed issues can serve to formulate the following guidelines on how to improve the debate about nuclear energy. A focus on responsible experimentation would shift the debate away from an absolute acceptance or rejection of nuclear energy. Rather, it would focus on more specific conditions under which responsible experimentation with nuclear energy might be acceptable. These conditions should include, but are not limited to, competent engineering and management of technology, democratic decision-making and legitimation and considerations of distributive justice.

In democratic debates, emotions should further be taken seriously. Rather than ignoring them as in the technocratic pitfall or taking them to be endpoints of debates, as in the populist pitfall, emotions should be seen as the starting point in debates about nuclear power. This makes it possible to focus the debate on important ethical issues that need to be addressed and discussed. Such an open discussion can help to overcome the stalemates that now dominate the debate about nuclear energy. This will pave the way for well-grounded and well-informed policies on nuclear power technology, taking the different perspectives into account.

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