The debate on nuclear energy for sustainability: A comment

The role of nuclear energy to cut down on greenhouse gas emissions continues to be a contentious issue in many countries. Public debate is often convoluted and largely revolves around price and costs of energy production technologies as well as their contribution to climate change. Here, we first dissect two interwoven factors bound to produce confusion in the price-cost debate: temporal discounting and external costs. We then explore how a stronger focus on risk ethics could contribute to the debate on nuclear energy for sustainability.

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Whether and to what extent nuclear power can serve climate change mitigation is subject to intense public debate in many countries (Friederich and Boudry 2022, Jarvis et al. 2022, von Weizsäcker and Kemfert 2022). In 2021, following a technical assessment by the European Commission Joint Research Centre (ECJRC) (Abousahi et al. 2021), the European Commission included nuclear energy in its taxonomy for sustainable activities, effectively declaring investments in nuclear energy to be considered environmentally sustainable. Notably, the ECJRC (Abousahi et al. 2021, p. 34) remarks that "although a substantial body of literature exists on the assessment of sustainability of different electricity generation technologies, not many studies address nuclear energy".

Political and societal discourse about energy policy often revolves around prices, costs and environmental sustainability. During much of 2022, energy prices were a dominant theme in the media (Kastrati et al. 2023). As to prices and costs, a crucial issue are externalities or external costs. Externalities are societal costs that are not reflected in market prices, but which still accrue. Since comparisons of energy sources are usually made solely based on market prices, some share of their total economic costs will not be accounted for. Given that external costs vary with technology, any such comparison will be biased. Because of the importance of external costs, attempting monetization of the real or "true" cost of different energy production technologies is still a focus of current research (e. g., Sovacool 2010, Rabl and Rabl 2013, Sovacool et al. 2021, Gries 2017). Unfortunately, any attempt of monetization is necessarily controversial, because it hinges on difficult modeling choices that involve ethical questions that are more implicit than explicit. To date, the debate about the "true cost" of energy remains convoluted, normative and hard to navigate at best. Consequently, the question arises whether making the ethical dimension of the issue more explicit could contribute to clarification.

Against this background, our contribution is to highlight some of the ethical aspects in the discussion about nuclear energy for sustainability. We start by reviewing the often implicit ethical dimension of two prominent and interwoven economic aspects of the discussion, temporal discounting and external costs. We then explore the problem of nuclear energy through the lens of risk ethics. We focus on these particular issues, because we find that 1. making explicit the normative stance required in modeling externalities could help disentangle the debate and 2. it is reasonable to ask if risk ethics can close some of the gaps concerning a high-risk technology such as nuclear energy.

Implicit normativity in modeling external costs

This section focuses on two issues that plague the debate about the real cost of energy. The first problem is concerned with valuing future costs. The second problem is omission of costs that should be included. In particular, we focus on the issue of having to take a normative stance towards the future and how this relates to externalities.

Temporal discounting, done right

One of the key issues in sustainability is the relationship of currently living humans and potential future generations (Becker

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	MIN [5%]	MAX [5%]	MAX [1%]	MAX [0%]
long-term health costs	0.053	0.119	0.119	0.119
agricultural losses	0.069	0.138	0.439	0.696
tailings management	0.034	0.326	0.326	0.326
Uranium mining total external costs	**0.156**	**0.583**	**0.884**	**1.141**

TABLE 1: Uranium mining external costs in Eurocents per kilowatt hour (€cents/kWh) with discount rates applied in brackets. Own calculations of best-case scenario (min) and worst-case scenarios (max) given by the discount rates, based on Wippel (2014), Jones (2017) as well as Aldy and Viscusi (2008).

2012). Future generations – given that they will exist at all – will have to live with the consequences of our decisions, yet are not partaking in our decision-making processes. While this fact cannot be changed, in some cases it is possible to estimate future costs[1]. It therefore seems reasonable to, in some limited sense, "give the future a voice" by relating costs that will accrue in the future to the present when we actually take a decision. The standard way of doing so is calculating a net present value of costs, that is their valuation in value units of today, which typically requires an annual discount rate, which expresses a stance towards the future as follows: "According to a Social Discount Rate, the present moral importance of future events, especially benefits and losses, declines at a rate of *n* per cent per year" (Parfit 1984, p. 480).

Clearly, the choice of a Social Discount Rate is a normative question intertwined with a methodological choice, which entails some degree of controversy to this day, albeit most economists seem to agree with a rate of 2% (see an acutal survey among 200 economists published in the *American Economic Journal,* Drupp et al. 2018). One morally defensible reason for a low positive discount rate is the possibility of human extinction (cf. Stern 2007), but this scenario is rarely explicitly acknowledged or discussed. The standard economic argument in favor of discounting the future though is that future generations will be better off due to our current economic activity (Arrow 1999). In discussing this reason for discounting, philosopher Derek Parfit (1984, p. 484) comments

> *The ground for discounting these future benefits is not that they come further in the future, but that they will come to people who are better off. Here, as elsewhere, we should say what we mean. And the correlation is again imperfect. Some of our successors may not be better off than we are now. If they are not, the arguments just given fail to apply.*

While our economic activities might benefit future generations, in particular each and every of their individual members, this is only one possible future among many others. Today, we cannot know which scenario for the future is going to materialize eventually. Taking for granted that future generations will be better off constitutes what philosopher Matthew Rendall (2019) calls an "ecological fallacy", because it neglects potential futures in which our successors are worse off. Therefore, this is not a valid argument to serve as a justification for an across-the-board discounting of the future.

While some philosophers like, for example, Parfit and Rendall think that no good reasons for discounting the future exist, most economists seem to agree that it can be justified, yet without reaching any consensus as to the preferable value of the Social Discount Rate (see Drupp et al. 2018). However, the choice of a concrete value for the discount rate is the key driver of any result obtained in studies where it is employed (see Groom et al. 2022). Importantly, this applies to any method of life cycle assessment such as the common levelized cost of energy as well as to studies that estimate external costs. For example, in their comparison of external costs of nuclear and renewable energy, Rabl and Rabl's (2013) calculations are based on a 5% discount rate, thereby meeting Nordhaus' (2007) arguments for this relatively large value in the context of climate change. However, a 5% discount rate is, in Parfit's framing, equivalent to saying that the "present moral importance" of one Euro of expenses that will have to be paid in 50 years from now is 0.09 Euros. This may be acceptable when expenses are construction costs and the like, but it seems morally debatable to apply such high discount rates to long-term health costs, including actual deaths, from radiation, sea-water contamination or agricultural losses due to land contamination.

External costs of nuclear energy

A second major challenge is to account for all sources of costs, in particular externalities. For example, a significant cost source is uranium mining externalities, but surprisingly little is published on these[2], so that they often remain unaccounted for in actual external cost comparisons (see, e.g., Rabl and Rabl 2013). Based on estimations by Wippel (2014), Jones (2017), Aldy and Viscusi (2008) and own calculations[3], external costs of nuclear

1 We focus here on costs, but the arguments are applicable to (net) benefits as well.

2 For example, as of April 18, 2023, a *Web of Knowledge* search on "uranium mining externalities" yields two hits while a query for "uranium mining external costs" yields six hits. A larger body of literature seems to be concerned with "mining externalities" in general (225) followed by "tailings management uranium" (179). In the latter case however, we could not find a contribution from economics with almost all hits being concerned with natural science aspects of the issue.

3 According to Wippel (2014), one kilogram natural uranium, or "yellowcake", (U3O8) entails ten metric tons of tailings, but contains only about 0.7% of U-235, which is used in nuclear reactors. Production of one kilogram U-235, which produces 24 million kilowatt hours, thus requires 1/0.007 ≈ 142.9 kilograms of natural uranium, which entail the production of 1429 tons of tailings. Cost estimates for tailings management are in the range of 6.34 US-Dollar per ton and 60.18 US-Dollar per ton. All figures are based on the 2021 global nuclear production of 2653 terawatt hours and in 2023 Euros or US-Dollars, applying a conversion rate of one Euro equals 1.10 US-Dollars (as of April 18, 2023).

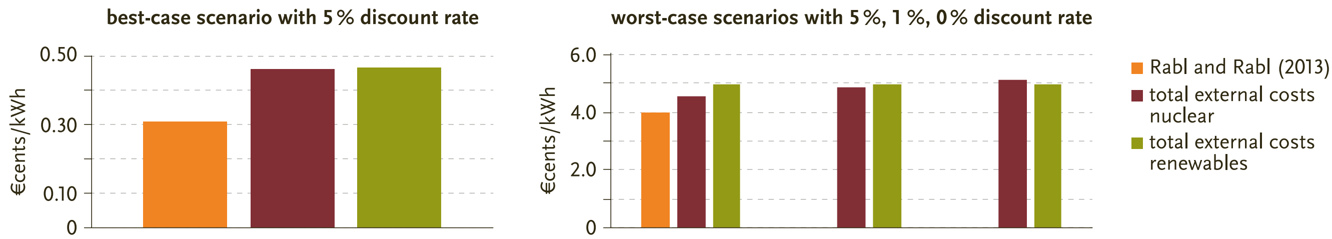

FIGURE 1: Nuclear and renewables: comparison of external-cost scenarios accounting for uranium mining externalities, best-case (left) and worst-case scenarios (right), with values from Rabl and Rabl (2013) as a baseline. Total external costs nuclear and renewables based on own calculations.

due to uranium mining are sizeable (table 1) and potentially enough to equalize any external cost advantage of nuclear over renewable energy using the estimates from Rabl and Rabl (2013) as a baseline (figure 1).

Table 1 shows that external costs of nuclear from uranium mining are at least 0.156 Eurocents per kilowatt hour, that is Rabl and Rabl's best-case scenario (0.31 €cents/kWh) accounts for only about 66 % of the external costs of nuclear energy when uranium mining externalities are included (figure 1, left panel). In the respective worst-case scenarios, the gap between nuclear and the alternative mix decreases with decreasing discount rates and vanishes completely with very small discount rates (see right panel of figure 1), highlighting the connection to the issue of temporal discounting as discussed in the above section on temporal discounting.

Finally, note that the *total* external cost of nuclear energy is much larger than the values just presented. For example, the mean estimate of total external cost of nuclear from 16 different sources in the peer-reviewed literature is 14.14 Eurocents per kilowatt hour (Sovacool 2010, p. 110, adjusted for inflation). Indeed, recent literature on expected damages from nuclear accidents based on historical data seems to support even larger external costs (Wheatley et al. 2017), not accounting for complex system dynamics that are hard to anticipate (Matsuzaki et al. 2012) and far-reaching (von Wehrden et al. 2012, Gralla et al. 2014).

In conclusion, due to the reasons presented, the true cost of (nuclear) energy is hard to assess and cost assessments may vary considerably, which creates the opportunity for politico-societal actors to cherry-pick those results that best fit their respective agenda.

Can risk ethics fill the gap?

Consequentialism and deontology

Economics, where it tries to make normative prescriptions on what best to do, follows a consequentialist ethical paradigm. That is, the morally relevant fact about an act is its (aggregated) consequences. In the case of risk, it is the probability distribution over (aggregated) outcomes that matters. As shown in the previous section, there are methodological challenges in valuing outcomes such as external or total costs of a technology. Still, the consequentialist approach seems relevant, because it translates concrete decision problems into analytically tractable optimization problems.

The aggregate nature of consequentialism poses some problems, in particular with respect to the concepts of individual rights and justice (Nida-Rümelin et al. 2012). These concepts are of particular relevance if a technology features catastrophic risks such as a large nuclear accident in, for example, Western Europe, the northeastern United States or China (see Lelieveld et al. 2012), in particular when comparing it to other technologies that do not feature such risks as in the comparison of nuclear and renewable energy, and the risk of another large accident is likely not minor. For example, Engler (2020) finds that nuclear reactor safety would have to be substantially improved over the empirical track record to reduce the risk of another Fukushima- or Chernobyl-sized accident event anywhere in the global reactor fleet below 5 %. Recent empirical estimates on reactor safety suggest this probability to be as large as 19 % assuming a reactor life span of 60 years (Engler 2020, p. 4). Since most nuclear power plants, especially those in Europe, are located in densely populated areas, this may seem unacceptably large even from a purely consequentialist perspective alone.

Deontological risk ethics and nuclear energy

It seems crucial to ask if it is morally acceptable to take such catastrophic risks, not only from the viewpoint of aggregate consequentialist risk optimization, but also from the perspective of individual rights and justice (deontological risk ethics, Nida-Rümelin et al. 2012). For example, if consequentialist optimization implied harming people, then this option to act would be morally unacceptable. Importantly, while the defining feature of risks is that they may or may not materialize, our moral judgments should not be contingent on whether catastrophe materializes or not. Nida-Rümelin et al. (2012) refer to this as argument "against moral chance".

From a deontological perspective, there is an individual right to health and physical integrity, but there is no right to get exposed to a risk that one finds acceptable (Nida-Rümelin et al. 2012). Thus, large collective risks that go beyond a level that is usually accepted as a part of everyday life without further discussion[4] such

4 Examples for such everyday risks are driving a car or riding a bike with the risk of injury or death in an accident, or meeting other people with the risk of contracting viral or bacterial infections.

as those from operating a fleet of nuclear power plants, require a societal discourse with integrative democratic decision processes. This is so for two reasons: 1. it is impossible to restrict such risks to those individuals who deem them acceptable; 2. the individual right to health and integrity demands that persons get exposed only to those risks to which they have democratically agreed to be exposed to. Indeed, looking at the history of nuclear power, such processes have largely been missing and the lack of discourse and participation has played a vital role in fueling public opposition against nuclear power (see, e.g., Patterson 1986, pp. 111 ff.). In fact, exactly when and how states have a duty for (transboundary) public participation in nuclear activities has only recently started to be discussed seriously (see, e.g., Duvic-Paoli and Lueger 2022).

Many arguments frequently given in favor of nuclear energy gloss over or ignore aspects of individual rights and justice, and instead take an aggregate consequentialist stance. These include nuclear's low[5] amount of emissions (Kainuma et al. 2012, Horvath and Rachlew 2016), its relatively steady levels of electricity (Grimes and Nuttall 2010), or its low expected number of casualties compared to other energy sources (McCombie and Jefferson 2016). However, from the perspective of deontological risk ethics, these arguments are morally unacceptable, because they seek to justify violating the individual rights of some persons to save a greater number of other persons from the violation of their individual rights.

The risk from operating a fleet of nuclear power plants is different from the risk from not operating it (Wheatley et al. 2016). Unfortunately, this may create a dilemma in that not using nuclear energy might imply increased reliance on fossil fuels (Friederich and Boudry 2022, Wheatley et al. 2016). Because we cannot plausibly rule out the tail risk of future catastrophic climate change even for relatively modest emission scenarios, this risk should be taken very seriously (Kemp et al. 2022). The result is a genuine dilemma: if we choose to not operate nuclear power plants today, this may mean that, instead of imposing a risk on ourselves, we impose it on future human beings by emitting more today. In doing so, we would then violate the individual rights of members of future generations. Moreover, adding further complexity to the dilemma, even large nuclear accidents or worst-case leakages, though costly for societies (Wheatley et al. 2017), will likely be limited in geographical scope[6], while climate change is and will remain a global issue.

Possibly the strongest argument against nuclear energy is the risk of nuclear proliferation. Nuclear war is still a primary security threat of our time (Ackerman and Potter 2008, Ord 2020), because of the expected global effects on humans, ecosystems and climate a large-scale nuclear war would entail (e.g., Robock et al. 2007, Cirincione 2008). Its global effects are rivaled only by those caused by natural risks such as supervolcano erruptions or asteroid impacts (Baum 2015). Weapons-grade fissible material is under strict international regulation and control (Ackerman and Potter 2008), but occurs as a natural waste product in all types of nuclear reactors (e.g., Frieß et al. 2015). Indeed, India, Pakistan, South Africa and Israel obtained their weapons fuel through their civil nuclear energy programs (see Friederich and Boudry 2022 and references therein). This is not to say that weapons fuel cannot be obtained differently (see Ackerman and Potter 2008 for a discussion), but to establish a link between civil use of nuclear energy and nuclear proliferation given a nation-state's sufficient motivation to obtain nuclear weapons. Ultimately, a case can be made that a fleet of nuclear arsenals carries a large risk of eventual nuclear conflict in the long run even if annual conflict probability is low (Rendall 2022), akin to a coin showing tails eventually if tossed often enough, even when it has a probability of showing tails close to zero on any single toss. If this is so, then the argument against moral chance would permit further expansion of nuclear energy to prevent further nuclear proliferation.

Conclusions

Public debate about energy sources often largely focuses on costs and prices. This focus is limited and often hampered by either neglecting the normative aspects of assessing the total economic costs of a technology or by neglecting certain external costs. As a result, despite its clear focus on one single metric, the debate is hard to navigate and unsatisfactory. The risk-ethical view on nuclear energy suggests that pure consequentialism does not suffice and that the deontological view may be better suited. Many arguments frequently brought forward in favor of nuclear are consequentialist and fail to account for aspects of individual rights and justice. However, the deontological perspective also reveals that not using nuclear may create a dilemma with respect to future generations, with nuclear proliferation and the associated risk of nuclear war as the strongest counter argument against the expansion of nuclear energy for sustainability.

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5 The amount of emissions from nuclear is contested and may well be larger than frequently claimed (see Wealer et al. 2021).

6 This does not mean that this scope is small by any means, but merely that it is very likely not global.

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