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(Radiation Protection and Climate Ethics, and the Case for New Nuclear Build Projects)

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Abstract. Across the world we are seeing a resurgence in nuclear new build with a current estimated 160 new reactors planned for construction and an additional 300 proposed. However, the ethics of nuclear power is increasingly under challenge due to the incidents at the Chernobyl and Fukushima Daiichi nuclear power plants, and concerns over radioactive discharges, safe management of radioactive waste and lack of an operational repository for spent nuclear fuel. Central to these concerns is the perceived "unique" radiological risk of nuclear power. But in a world where Climate Change presents a threat to the entire planet, is nuclear power and the associated radiological risk not ethical? Exploring the interplay between climate change ethics and the ICRP's System of Radiological Protection, we consider the major contribution that new nuclear power stations can make to climate change mitigation, through decarbonisation of power systems, and finally unpick the case for nuclear power in this new world of climate change ethics.

KEYWORDS: *Radiation Protection Ethics, Nuclear Power, Perceived Risk*

1 INTRODUCTION

The threat from climate change is real and growing. In order to reach net zero emissions by 2050 [1, 2], we are in desperate need of a 'just' energy transition. To achieve this energy transition, we need to consider all forms of available low-carbon technology and we need to judge each technology fairly and evenly. One such option for the low carbon energy transition is nuclear power. Currently, there are 100 nuclear power reactors - representing a total gross capacity of 120,000 MWe – on order or planned worldwide. In the UK, for example, there are two EPRs being built at Hinkley Point C (HPC), in Somerset, and there are two more planned to be built at Sizewell C (SZC), in Suffolk, and two HPR1000 reactors planned for Bradwell B. Roughly 20% of UK electricity demand could be met with firm, low carbon power – if these reactors come online.

The contours of the nuclear regulatory landscape are shaped by the International Commission of Radiological Protection's 'System of Radiological Protection', as set out in ICRP Publication 103 [3]. This system contains within it three guiding principles for radiological protection: justification, optimisation, and application of dose limits. It is through the analysis of these principles that we propose to explore the ethical case for new nuclear builds – and subsequently understand the interplay between public perception of radiological risk and the current regulatory approach.

In section 2 of this paper, we will outline the ethical obligations that climate change generates. We will then use section 3 to explore how these obligations relate to development of new nuclear power stations, foregrounding the UK as an example, and also explore the role of other technologies in the mitigation of climate change. In section 4, we will seek to understand the regulatory principles that undergird all current approaches to radiological protection. We will then apply these principles, in section 5, to the context of new nuclear build projects, considering their interaction with the wider field of climate change ethics. Finally, we will outline the case for new nuclear build projects in the context of climate change and radiological protection ethics.

2 ETHICS, CLIMATE CHANGE, AND THE ENERGY TRANSITION

Climate change is increasingly understood as an intractably wicked problem [4], representing a broad church of negative social and ecological impacts. Increasingly, it is becoming clear that "disadvantaged and vulnerable communities" are disproportionately exposed to climate risks [2]; that there is an increased likelihood of severe and traumatic weather events in the medium- to long-term [5]; and that current systemic injustices are likely to be perpetuated [6]. Thus, climate change threatens to destabilise our current social and political systems, whilst amplifying inequality and severely impacting the most vulnerable on our planet. It is through this conceptualisation of climate change that we derive the imperative to halt its progression and work to minimise its impacts. In order to do this, whilst also ensuring that our approaches remain equitable and fair, we need to navigate the complex technological and political challenges that climate change prevention entails.

Ethics is the practice of judging right from wrong [7]. In the context of climate change, this field of practice can: clarify our obligations to act (or not to act) [8], challenge our understandings of risk-imposition-permissibility [9], and provide a toolkit with which to navigate a world of competing technologies and 'climate solutions' [8, 10]. In short, ethics – as a field of practice – provides a framework for achieving an equitable outcome to some of the most difficult challenges of our time.

To halt the progress of climate change, whilst minimising the risk imposed on the Earth's populations, we are faced with two options: mitigation and adaptation. Mitigation involves the prevention of "dangerous anthropogenic interference" [11] so as to limit the increase of global average surface temperature to 2ºC and, hopefully, "keep the warming well-below 1.5ºC" [12] – this would help to avoid the worst impacts of anthropogenic climate change [2]. Adaptation, on the other hand, is an approach to managing the increased risks that are generated by climate change – some of which we are already committed to under current levels of warming – which could include everything from protecting coastlines from rising sea levels, through innovative engineering approaches, to changing current approaches to insurance. In order to reduce the overall risk imposed on the Earth's populations, both adaptation and mitigation are required to effectively tackle climate change. In order to assess the viability of different technologies, it is, however, helpful to understand approaches to mitigation and adaptation independently.

In this paper, we will explore the decarbonisation of the energy system – as a form of mitigation – in-depth. Decarbonisation often requires a large scale 'energy transition'. In the UK, for example, 25.6% of emissions in 2019 came from energy supply [13] – a large majority of these emissions represented by emissions from gas-fired power stations [13]. In order to meet 'net zero' emissions by 2050, the UK government would need to commit to moving away from high carbon technologies and installing new low carbon generation on the grid. The options for this kind of transformation include wind, solar, gas or bioenergy with carbon capture and storage (CCS), hydropower or nuclear. In order to adopt any of these technologies, as Jamieson [14] explains, we are going to need to accept that, no matter what choices we make, there will be costs and benefits to the path that we choose. Ethical frameworks provide us with a means of navigating these trade-offs, hopefully, in the long run, allowing us to achieve a more equitable world for all. First though, what role can different technologies play in our race to 'net zero'?

3 NUCLEAR POWER AND OTHER TECHNOLOGIES

In order to meet the UK 2050 'net zero' emissions ambition [15] we are going to need to see the rapid decarbonisation of all sectors, including the energy sector. As we begin to electrify transport and heating this challenge will increase – with the UK Committee on Climate Change estimating a doubling of electricity demand by 2050 [16]. The majority of this electricity will need to come from low carbon sources. This means that we not only need to replace existing carbon-intensive forms of electricity generation, but that we also need to deploy a low carbon fleet that is large enough to meet increasing demand for electricity.

The need to ensure that we move away from fossil fuel-dependent forms of electricity generation, like gas and coal, and move towards low carbon energy sources is clear. In order to achieve this, the UK will need to choose between a large suite of technologies. This list includes solar, wind (onshore and offshore), gas or bioenergy with CCS, and nuclear.

Making the choice between these technologies is no easy task, as each has something different to offer. Their purported benefits range from increased grid stability to low, or even negative, carbon emissions to long-term job prospects. The adoption of one technology does not, however, have to be to the exclusion of other technologies. In fact, the Committee on Climate Change has suggested that a large suite of technologies will be needed to achieve 'net zero' emissions by 2050 [16].

Alongside renewables, nuclear power can act as a key enabler of the low carbon transition. For over 60 years, the UK has had nuclear power contributing to its energy mix – providing a broad suite of well-paid, long-term jobs. In 2019 alone, nuclear power in the UK avoided roughly 17.8 MtCO2e, equivalent to 8.1 million cars coming off the road for a whole year [17]. In fact, the nuclear industry has also provided a broad suite of well-paid, long-term jobs. By 2030, however, all but one of the nuclear power stations, Sizewell B, that are currently online in the UK will have been turned offline. This means that the UK will be faced with a deficit of low carbon baseload power. In order to fill this gap, the UK will need to establish a new nuclear build programme. The UK Government has recently committed to this in their 10 Point Green Recovery plan [18] and National Infrastructure Strategy [19] - however, clarity is still lacking from these plans. What then is hindering the decisive inclusion of nuclear technology in the suite of approaches that are currently being adopted and employed by the UK Government?

In reality the primary resistance to new nuclear can be grouped into two broad categories: (1) those local concerns which are applicable to any large infrastructure such as the disruption created during the construction and the sight of the infrastructure following construction; and (2) those concerns that are unique to nuclear power, which are strongly associated with radiation-phobia and radioactive waste management. Despite negative local concerns, we are still seeing the large-scale deployment of wind, solar, and BECCS (bioenergy with CCS) technologies (for example, [20]). Although addressing local concerns is a crucial part of ensuring the viability and equitability of any large infrastructure project, the unique concerns surrounding nuclear require specific focus as they are playing a significant role in limiting the deployment of new nuclear power.

There is no doubt that historical events such as the accidents at the Chernobyl and Fukushima Daiichi Nuclear Power Plants have played a role in the negative perception of radioactivity. But is the level of concern and fear a fair reflection of the risk of radioactivity compared to the other day to day risks we come across such as crossing the road or driving a car? And does this level of concern and resistance provide an ethical argument for not pursuing nuclear power despite its obvious benefits?

To understand this, we need to look at the current approach to radiation protection, and consider whether these questions are adequately covered.

4 SYSTEM OF RADIOLOGICAL PROTECTION

In order to ensure adequate protection from radiation for the public and workers, the International Commission on Radiological Protection has established a 'System of Radiological Protection' [3] that sets out three core principles for radiological protection: the principles of justification, optimisation, and application of dose limits. Through these principles the international and domestic regulatory framework for radiological protection is established.

4.1 Justification

The first principle, justification, establishes the idea of doing "more good than harm" [3]. In this, the ICRP introduces the idea that "one should achieve sufficient individual or societal benefit to offset the detriment [that the exposure situation] causes" [3]. By this, we can understand that although the creation of a new exposure situation may not be ideal, it can be justified if it brings about sufficient benefits – both social and economic.

The ICRP advises that the issue of justification should be a consideration of governments or national authorities so as to "ensure an overall benefit in the broadest sense to society" [3] is achieved. Further, the Commission understands that "radiological protection considerations will serve as one input to the broader decision process" [3].

In its broadest sense this principle strongly aligns with the definition of ethics, in that it requires a judgement to be made between what is "right and wrong", but recognising that this is not black and white, and cannot be determined by any one factor on its own.

4.2 Optimisation

The second principle, the principle of optimisation, establishes the idea that "the likelihood of incurring exposures, the number of people exposed, and the magnitude of their individual doses should all be kept as low as reasonably achievable" [3]. On top of this, the ICRP has reasserted the need to take into account "economic and societal factors" [3] as part of the optimisation process.

By this, the ICRP means to ensure that the ethical argument does not stop with whether the practice, such as nuclear power, is justifiable, but whether the level of exposure to ionising radiation, and therefore potential health detriment, is also "ethical".

In this the ICRP aims to ensure that the decision making process, to determine the optimised level of exposure or risk, identifies the "right" outcome. However, determining this optimal level has its challenges and the desire to pursue lower and lower exposures, if left unchallenged, can lead to the "wrong" outcome by putting a greater emphasis on radiation, compared to other factors, such as non-radiological hazards or the societal impact.

4.3 Application of Dose Limits

The third principle relates to the application of dose limits, namely that the "total dose to any individual from regulated sources in planned exposure situations other than medical exposure of patients should not exceed the appropriate limits recommended by the Commission"

By setting these limits the ICRP are aiming to ensure that under planned conditions, an adequate level of protection is ensured and that individuals are not exposed to an unnecessarily high amount of ionising radiation.

On this basis exceeding a dose limit is contrary to regulations in most countries. However it is important to note that these cannot be applied in isolation and work in combination with the principles of justification and optimisation.

5 APPLICATION OF PRINCIPLES

The 3 principles represented in the ICRP's System for Radiological Protection offer a means of differentiating "right" from "wrong", in the context of radiological exposure and risk. When pairing these principles with the obligations that the ethics of climate change establish – the need to reduce anthropogenic greenhouse gas emissions, and the need to ensure that mitigation approaches are fair and equitable – we can begin to discern whether the development of new nuclear power stations in the UK is "right" or "wrong".

Do new nuclear build projects meet the obligations established through the ethics of climate change?

Nuclear power represents a massive opportunity to reduce the anthropogenic greenhouse gas emissions from electricity generation. Once constructed, nuclear power stations effectively produce zero carbon emissions. Further, a new build programme represents a huge boost to local economies, both through job creation and tertiary benefits [21]. This scenario is already playing out near the Hinkley Point C construction site [22], and is projected to continue in Suffolk if the Sizewell C project goes ahead [23]. As such, a new nuclear build programme would not only represent an opportunity to further decarbonise the UK electricity system, but it would also represent an equitable outcome for many local communities – provided local participation is encouraged, and local concerns are addressed.

Beyond this, recent proposals have shown that nuclear power has the potential to produce benefits that are auxiliary to low carbon electricity generation. These benefits may include the production of low carbon hydrogen or could even include the development of direct air capture (DAC) [24]. So, nuclear power may not only produce low carbon energy but could also provide a set of resources that could accelerate the UK's transition to a low carbon economy.

Some may be concerned about the emissions produced during construction; however, the lifecycle emissions of a nuclear power station are competitive with those seen in renewable technologies [25]. Similarly, some may be concerned that the expansion of new nuclear power might displace other cheaper forms of low carbon energy. Whilst a valid concern, it has been shown that new nuclear power in the UK could work in tandem with new renewable power – providing baseload power when the wind isn't blowing or the sun isn't shining – to provide grid stability, and it may actually work to reduce overall system costs [26] therefore representing a win for the consumer. As such, it is clear that new nuclear build projects meet the obligations established through the ethics of climate change.

Do new nuclear build projects meet the standards established through the ICRP?

In 2010, the Department of Energy & Climate Change, acting as the UK's justifying authority, produced a report [27] detailing its reasons for justifying the use of new nuclear power within the UK. It weighed up the benefits and detriments of new nuclear power taking due consideration of carbon reduction, security of supply, radiological health detriment, radioactive waste, environmental detriment, safety, security and safeguards.

The output of the assessment concluded that the case for new nuclear power was "justified by its economic, social and other benefits in relation to the health detriments it may cause" [27]. In essence the benefits were judged to outweigh any negatives, and the decision to pursue new nuclear power was deemed to be "right", on the basis of its ability to "secure the UKs energy supply, helping the UK decarbonise and meet legal low-carbon obligations and benefiting the economy more widely" [27].

When contemplating the principle of optimisation, it is instructive to consider whether it would be "right" to spend £100 million on reducing the radiation exposure from routine discharges from a New Nuclear Power Station from 2 μSv to 0.2 μSv (e.g. from 1000 times less than natural background to 10,000 times less than natural background) or spending that money on improving health and safety during construction of the power station, from conventional hazards such as working from height, for example. Recognising this challenge ICRP clearly states that "[optimisation] of protection is not minimisation of dose" [3] and that the best option is not necessarily the one with the lowest dose.

Finally, the current dose limits in the UK align with those proposed by the ICRP.

From this, we can see that the development of new nuclear power stations currently meets the standards set out under the ICRP's System for Radiological Protection.

So, as long as the use of nuclear power is justified, and the levels of exposure suitably optimised, is nuclear power ethical? And should new nuclear build projects be pursued?

Public concern represents a significant barrier to the ethical deployment of new nuclear power stations. This concern may be driven by a combination of a lack of information, by the memory of past nuclear incidents, and by risks being misrepresented to the public. If concern, as a result of misrepresentation of or misinformation on risk, is resulting in unnecessary stress and fatigue, then it cannot be said that the needs of local communities are being met – as such, this issue needs to be addressed in order to ensure the ethical viability of new nuclear power. The application of the principle of optimisation, in this context, may hold the solution and has been previously discussed in several international workshops hosted by the International Radiation Protection Association (IRPA) and French Society for Radiological Protection (SFRP) in February 2017 and October 2018. The output of the workshops is captured in Bryant *et al.* [29] and Lecomte *et al.* [30] and emphasised the importance of:

- a holistic view of optimisation taking into account all hazards, not only radiation;
- development and implementation of structured approaches and "tools' to pursue ALARA;
- engagement with all stakeholders involved in the exposure and decision-makers involved in the optimisation process; and
- a commitment from all those involved in the process, or as it is more commonly known radiation safety culture.

This shows that engaging with all stakeholders involved in the exposure (including the public) presents an opportunity to reduce concern and ensure individuals can come to their own informed decision on what is the optimised level and why that is ethical. This process of participation represents a way of navigating negative public perception such that an ethical outcome may be ultimately attained.

Although the case for nuclear, as seen in the UK, can be justified both under the ethical obligations that climate change entails, and through the ICRP's System of Radiological Protection, there are external forces beyond negative public perception that are stymying the deployment of new nuclear power. The World Nuclear Association has shown that:

> "economic, regulatory and political considerations have led to the premature closure of some nuclear power reactors, particularly in the USA, where reactor numbers have from a high of 110 to 97, as well as in parts of Europe and likely in Japan" [28].

Furthermore, and despite the 'As Low As Reasonably Achievable' (ALARA) Principle that is established through the Principle of Optimisation, the nuclear industry is often seen as trying to achieve minimum dose. This is in spite of the impact that this pursuit is having on the viability of a new nuclear build programme: increasing costs, and driving public misperception that the normal running of a nuclear power station produces a significant radiological risk. This ultimately threatens the long-term viability of new nuclear power – both ethically and economically.

6 CONCLUSION

Although we have been unable to cover all details of this thorny issue in-depth, we have begun to uncover the complexity that surrounds the development of new nuclear power stations – using the UK as an example throughout. In particular, we have shown that nuclear power may not only present the "right" thing to do, in the context of climate change, but also that it is viable within the bounds of the ICRP's System for Radiological Protection. In doing so, we have also highlighted the impact of political and social factors – including public misperception of risk – in limiting the useful deployment of new nuclear power in the UK. Nuclear power represents a potentially important part of achieving 'net zero' emissions. Thus, it would not only be remiss to limit its inclusion in our suite of potential solutions, it would also be "wrong" to exclude it out of hand.

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