Trust, justice, and expertise in nuclear waste management: a Q-method analysis of environmental discourses in the United Kingdom

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Abstract

Nuclear waste is ethically contentious, concerning institutional trust, community engagement and the role nuclear plays in different sociotechnical configurations of energy futures. Using Q-methodology with a diverse UK-based stakeholder group, we find three emergent discourses: a) “Managing a distrustful public,” b) “Fair and democratic nuclear waste decision-making,” and c) “Putting the experts in control.” Though multi-stakeholder support is expressed for geological disposal of wastes, disagreements arise towards the ethics of nuclear-powered energy futures and to community decision-making roles. We recommend that policy authorities must first strengthen community withdrawal rights, and second, renew deliberative democratic decision-making mechanisms within energy policy strategy.

Keywords: nuclear waste management, environmental justice, Q-methodology, stakeholder conflict, environmental discourses.

1. Introduction

Nuclear waste poses a significant environmental governance challenge amid efforts to renew nuclear energy in many countries aiming to achieve net-zero emissions. Advocates argue that centralised low-carbon energy is essential to support the increasing demands on grid infrastructure from electric vehicles, domestic heating,

and to address the intermittency of renewable energy sources. Nuclear power is thus presented in contemporary energy policy in countries including the UK as an essential technology to halt the growing climate crisis (HM Government, N/D; Mathew, 2022). For others, issues of cost, radiation protection, plant failure, terrorism, nuclear proliferation and trans-generational nuclear waste management stimulate environmental concern and social opposition (Stirling & Johnstone, 2018; Blowers, 2010; 2020; Winner, 1980). At the tail end of the nuclear fuel cycle is the need for the long-term safe management and eventual disposal of nuclear wastes in a deep geological disposal facility (GDF). Waste production, management, and disposal entail intricate social and environmental justice considerations concerning the involvement of host communities, minimising environmental and ecological impacts, and the fair distribution of risks among regions, demographics, environments, and generations. This means that nuclear technologies are complex *sociotechnical configurations* that evoke contested landscapes of meaning amongst diverse stakeholder groups (Walker and Cass, 2007; Bergmans et al. 2015), and this study, using Q-methodology, explores these contested configurations of discourse, meaning and normative contestation in light of Government plans to radically expand nuclear capacity in the UK by 24GW(e) (GOV.UK, 2024), at a time when nuclear waste facility siting remains geographically and politically unresolved.

Conceptualised as a sociotechnical configuration, nuclear waste management is subject to the production of normative and political discourses that shape the pattern of policy strategies, technologies, actors, and institutional arrangements. In this article we aim to delineate emergent contemporary normative nuclear discourses that surround the issues of nuclear power and waste management. We use a combination of environmental discourse analysis and Q-methodology to reveal the *context* and *quality* of emergent discourses in contemporary civil society debate over nuclear technologies in the UK, and to delineate potential areas of stakeholder cooperation and conflict within normative policy debates (Aigbe et al. 2023), building upon previous work that used similar methods to specifically categorise the dimensionality of risk related to nuclear waste (Venables et al., 2009). In this analysis we expand the approach, using a combination of Q-methodology and discourse analysis to assess how people and institutions linguistically and interpretively construct nuclear sociotechnical combinations and governance processes, whilst Q-Method is used show the ways in which these discourses and are constructed and shared amongst a group of stakeholder representatives from industry, policy and non-specialised citizen-stakeholder backgrounds. As Bergmans and Simmons argue, much of the literature on radioactive waste management has focused upon “social factors” such as risk perceptions, whereas they suggest, we should:

> “… ask about ‘socio-technical combinations’. A lot of different factors are making up radioactive waste management. This ‘mess’ (or overflow of factors) is handled by different groups, working from various perspectives and having different responsibilities...” (Bergmans and Simmons, 2008, p.41)

It is through the application of Q-Method that we offer a novel contribution to the nuclear energy ethics and policy literature by connecting a diverse array of stakeholder positions to broader normative environmental discourses or shared worldviews on the sociotechnical combinations of contemporary nuclear energy and waste disposal, exploring the relationship between technology choice, linguistic constructions, ethical

principles, and value judgements surrounding contemporary UK nuclear waste management. The conceptual and methodological background to the study is explained in sections 2.

The remainder of the paper is structured as follows: part two details nuclear policy and discourse analysis; part three outlines Q-Methodology and its application to nuclear governance; part four present the emergent discourses from the Q-method study; part five discusses the relevance of emergent discourses to nuclear policy and practice; and part six offers conclusions for ethical and environmental policy research more broadly.

1.2. Nuclear waste policy background in the UK

The slow advancement in siting deep geological disposal facilities in many European and North American nuclear-producing nations is attributed to the disputed politics of nuclear waste. In the United Kingdom, decision-making on nuclear waste reflects a mix of the worst and best environmental governance practices over time. In its early history, nuclear power in the UK in the 1950s emerged during a period of techno-optimism and Cold War secrecy, leading to the side-lining of long-term waste management as an environmental concern (Blowers, 2010; Cotton, 2021). By the late 1960s, nuclear waste management at sites close to Sellafield in Cumbria, involved dumping radioisotopes into the North Sea, burying them in shallow trenches, or storing them in hazardous ponds (Cotton, 2017). A mixture of external diplomatic pressure on the dumping of radioactive materials at sea, and the 1976 Royal Commission on Environmental Pollution Sixth Report chaired by Sir Brian Flowers (RCEP, 1976), led to growing political recognition for a safe and publicly acceptable solution to long-term nuclear waste disposal. Deep geological disposal of nuclear wastes was soon seen as a moral imperative for environmental and public health protection, as well as a pragmatic political step to secure the future of the UK's nuclear energy programme.

The Nuclear Industry Radioactive Waste Executive (NIREX) initially handled site selection, employing a technocratic approach. However, Nirex's attempts in the 1980s to find a site for a Geological Disposal Facility (GDF) were politically controversial and ultimately unsuccessful (Murray, 2002). In 1997, Nirex faced challenges, including a failure to secure planning permission in West Cumbria, partly due to the 'decide, announce, defend' nature of the decision-making process, which resulted in overlooking local concerns about hydrology, hydrogeology, environmental impact, and decision-making transparency (Blowers, 2010). Under the former Labour Government site selection was halted and nuclear waste decision-making was reformulated as a participatory-deliberative process of technology assessment for nuclear waste management options under the independent Committee on Radioactive Waste Management (CoRWM) (Blowers, 2010; Cotton, 2021). A series of extensive stakeholder dialogues on the range of available technical options for nuclear waste management and disposal was considered. This led to a much stronger level of democratic accountability in support of deep geological disposal with the stipulation this must not be imposed on a community (Chilvers & Burgess, 2008).

After the Government accepted CoRWM's recommendations in 2007, a voluntarist site selection framework was introduced, involving community partnership and geophysical appraisal. The initial lead in this process was interest in investigating a site in West Cumbria, Northwest England with initial support from both Copeland

Borough Council and Allerdale Borough Council. However, the Cumbria Association of local councils surveyed local and parish councils finding only 8 out of 88 wanted to proceed to the stage of site investigation, with 43 actively opposed to the move (Cotton, 2017). The process stalled due to a lack of engagement with the meso- level or regional community (Cotton, 2018). In one sense the decision 'failed' as the scales of governance between local and regional political authority could not find consensus. However, the decision to withdraw from consideration was also a 'success' in that it provided a strong test of the democratic governance model. This involved refining of the process and guidance for developing community partnerships and testing public support for voluntarist site investigation.

This long history of siting policy failures in the UK illustrates the *wicked* (Rittel and Webber, 1973; Lönngren and Van Poeck, 2021) nature of the problem, which involves complex and interrelated factors making the problem difficult to both define and resolve with simple policy solutions (Di Nucci and Brunnengräber, 2017). Factors such as long-term risk assessment, the stewardship responsibilities of host communities, and the status of future generations are incomplete, difficult to define and remain in flux (Bergmans et al., 2015), and these are problems that the new nuclear waste management organisation Nuclear Waste Services Ltd face in their continued search for a willing host community. Understanding how specific actors within the nuclear waste governance space can "capture" specific technical, economic, environmental, ethical, and social narratives around geological disposal to form unique sociotechnical combinations of technology, governance and spatial orientations of nuclear facilities is important in explaining how certain solutions to the problem emerge, become reinforced within policy networks, and are then implemented at specific geographic and governance scales.

1.3. Nuclear waste as environmental discourse

When treated as a research problem we conceptualise nuclear waste in this analysis as an expression of environmental discourse. Discourse analysis (DA) approaches, grounded in the work of Hajer (1995) and Dryzek (2013) proves useful in this regard. At the broader 'macro' scale, discourses are a shared means of understanding the world (Dryzek, 2013) through which wholly different conceptualisations of environmental problems lead to very different solutions. For example, one could envisage nuclear power as a clean, modern energy solution to climate change; alternatively, one could envisage it as a risky technology sited too close to urban populations. In both cases the individual is concerned with the relationship between technology and social welfare, however, the former is expressed through a discourse of technological optimism to meet utilitarian aims of benefiting large populations (which Dryzek terms 'Prometheanism'), and the latter is one of risk governance and *egalitarian* environmental justice that emphasises fair treatment and individual environmental rights. Discourses also serve to structure 'micro-level' or community scale interactions, by shaping groups of utterances that link modes of thought and understanding to action (Talib and Fitzgerald, 2016). Discourses codify acceptable and legitimate knowledge, can facilitate or foreclose communication, and are nexuses of power in the sense that they can invest or divest in specific interests and agents (Dryzek, 2013). Discourses also therefore become the focal point for coalitions of actors to form around common definitions, framings, and suggested solutions of socio-environmental problems (Hajer, 1995).

The nuclear fuel cycle generates significant discursive contestation and debate. This concerns nuclear power's potential as 'baseload' electricity generation, as a solution to energy system decarbonisation, and as a source of hazardous wastes from uranium extraction, enrichment and spent fuel management, and thus of risk, public cost, and socio-environmental harm (Cotton, 2017). Researching nuclear waste governance as *discourse* builds understanding of shared problem framings and motivations, and how these coalesce into stakeholder action. By focussing on the role of language-in-use in environmental politics, we can see how the linguistic construction, interpretation and analysis of environmental problems has ramifications beyond individual environmental management practices (Dryzek, 2013). For instance, the use of metaphors to bring out the 'thisness' or 'thatness' of an object not only serves to familiarise or make things strange, but also can suggest certain solutions (Hajer and Versteeg, 2005). For example, in the extant literature on nuclear discourse Renzi et al. (2017) note that emergent discourse metaphors of *rebirth, devastation* and *sickness* pervade the dominant framings of nuclear power in public discourse. These in turn link to deeper social discourses of either: *utilitarianism* through which societal well-being is conflated with material well-being and economic growth from nuclear development (Hadjilambrinos, 1990), *Prometheanism* (Dryzek, 2013) through which human ingenuity and the application of energy can resolve (all) social problems; *peripheralisation* in which nuclear technology 'crowds out' other forms of socio-economic development from geographically remote and politically marginalised nuclear communities (Blowers, 2016); and environmental, energy and climate justice discourses which variably emphasise community rights, respect for identity, wellbeing and involvement of heterogeneous publics in decision-making processes (Jenkins et al, 2017; Shrader-Frechette, 2012). Nuclear technologies thus become 'empty signifiers' (Laclau, 1994) – essentially a lens through which to discursively frame broader issues of environmental justice, the ethics of technological advancement and the enhancement of social welfare.

When multiple and conflicting environmental discourses are brought to bear within contemporary environmental management debates, it is necessary to both delineate the range of social perspectives that emerge amongst competing stakeholder groups, and to also explore the similarities and differences between competing perspectives with a hope of reaching shared understanding (and potentially) tentative consensus on future action. Q-methodology is uniquely suited to explore the relationship between macro-scale discourses in environmental politics, shared worldviews on the nuclear waste challenge, and micro-scale discourses involving linguistic constructions, value judgments, ethical principles, and shared expressions related to environmental management options (Cotton, 2015).

2. Q-methodology and Application

Q-method was first developed by Stephenson (1964), as a means to 'objectively' study 'subjective' constructions around distinct social phenomena using a combination of inductive quantitative and qualitative research techniques, though has more recently been applied as a method for environmental discourse analysis (Barry and Proops, 1999). Q-method combines both statistical and post-positivist interpretive social analysis techniques. Unlike the more commonly-used social survey approach (sometimes referred to as R-method) which aims to test hypotheses to show

explanatory power over population, Q-method is an inherently inductive method useful in mapping the subjectivity that surrounds a topic from the standpoint of the individual experiencing it (Brown, 1996). Identifying and describing shared perspectives is valuable for understanding the range of values on a topic and defining areas of agreement and disagreement in public debate. Identifying shared perspectives via this method also provides specific benefits for studying contentious environmental concerns where stakeholder conflict shapes the sociotechnical combinations of waste management solutions resulting from policy choices (Aigbe et al, 2023; Bergmans et al, 2015; Forrester, 2015).

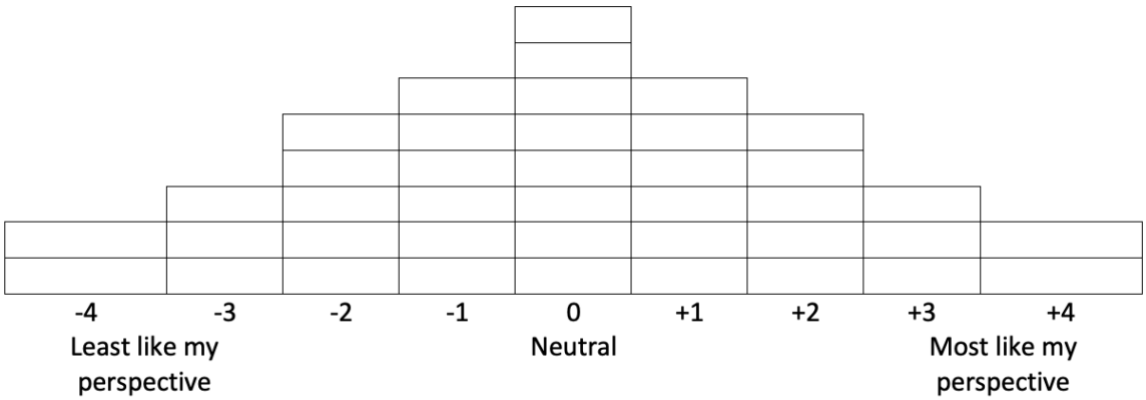
Our inductive Q-method study of shared social perspectives on nuclear waste governance follows a series of standardised methodological steps:

1. *Collect and sample statements.*

We used a combination of predefined (from database search) and secondary analysis of stakeholder-derived statements (the latter from workshops held in London, Sheffield, Munich and Barcelona with a mixed stakeholder group of citizen-stakeholders, industry and policy actors – none of which complete Q-sorts in this study). Statements are collected in an unstructured manner form online sources using keyword searches (*nuclear waste OR *radioactive waste, AND *public AND/OR *community AND/OR *ethics AND/OR *justice AND/OR *siting AND/OR *host). Sources included media content databases (inc. Nexis database), policy documents (inc. policycommons.net), and academic literature (inc. Google Scholar, Scopus), general internet search (Google). Transcripts of workshops were subject to similar keyword searches to source relevant utterances.

The collected statements (the concourse) were subject to a thematic analysis to develop common categories within the larger corpus. Text responses were then sampled within thematic categories to produce a smaller subset (the Q-set that is used for sorting shown in figure 1) – using an inductive and iterative approach such that statements were collected from each theme.

Figure 1. The Q-sorting grid



Duplicates were discarded and attention was paid to overall balance based upon user feedback through piloting with one social researcher and one citizen-stakeholder (checking for wording, complexity, and ‘valence’ so that there are not too many positive

or negative statements in each thematic category). Note that statement origin, and the themes for sampling are inherently subject to researcher bias as different researchers might find or choose different statements (van Exel and de Graaf, 2005); however, this is not considered a problem for Q-method research as participants bring their own meaning to the data based upon internal reflection, deliberation, sorting (ranking) and commentary on the statements and process itself (Coogan and Herrington, 2011). Meta-research on the process of Q-sorting shows that different statements, constructed in different ways from the same concourse, tends to produce similar conclusions irrespective of the sampling procedure (Thomas and Baas, 1992), thus providing confidence in the validity Q-method findings to capture the nature of differing social perspectives on substantive topics under consideration.

2. Selecting the participants (P-set)

Q-method data collection involves a small set of respondents (the people or 'P-set'), similar in size to that of a qualitative interview study, where typically the number of people is smaller than the number of statements being sorted (12-40 is common across the literature) (Webler et al., 2009). The aim is to capture diversity of perspectives towards the topic rather than true demographic representation. In this case we engaged with 25 participants, aimed to represent a diverse range of positions across research, industry, civil society and policymaking within the UK. Details of participants are shown in table 1.

Table 1. Stakeholder details and defining sorts for each factor

Q-sort number	Stakeholder details (Male [M], Female [F], Non-binary non-conforming [N]), Occupational sector	Factor A	Factor B	Factor C
1	F, Citizen-stakeholder, NHS	-0.101	**0.8614**	-0.014
2	M, Elected Councillor	0.0078	**0.868**	-0.0897
3	F, Citizen stakeholder, NHS	0.0078	**0.868**	-0.0897
4	M, Citizen-stakeholder, Self-employed	-0.2872	**0.6541**	-0.2004
5	F, Citizen-stakeholder, Climate research	0.1048	**0.7344**	0.1391
6	M, Citizen-stakeholder, Civil Service	0.4575	**0.6048**	-0.0626
7	M, Researcher in nuclear waste	**0.3995**	-0.0952	0.3233
8	F, Researcher in nuclear waste	**0.5902**	0.094	0.4477
9	M, Nuclear industry stakeholder	0.4187	-0.1626	**0.4863**
10	M, Nuclear industry stakeholder	0.433	-0.4473	0.4008
11	F, Citizen-stakeholder, Climate charity	-0.1493	**0.8907**	-0.0865
12	F, National nuclear waste policy stakeholder	**0.8157**	0.1235	0.2024
13	F, Research in nuclear waste	**0.7061**	-0.1458	0.2991
14	M, Nuclear industry stakeholder	**0.5829**	0.0762	0.1703
15	M, Nuclear researcher	**0.533**	0.3567	0.24
16	M, Nuclear researcher	**0.667**	-0.2831	-0.2991
17	F, Nuclear researcher	**0.7145**	0.3183	0.333

18	F, Nuclear researcher	0.0811	-0.3223	**0.8134**
19	M, Industry stakeholder, Stakeholder engagement	**0.6556**	-0.435	0.3289
20	M, Nuclear research	0.2536	0.0094	**0.6484**
21	M, Nuclear industry stakeholder	**0.4698**	-0.3158	0.3065
22	F, Nuclear research	0.1131	-0.0454	**0.7475**
23	F, Citizen-stakeholder, Teaching	0.0941	0.3687	**0.4976**
24	M, Nuclear research	0.5429	-0.1021	**0.5525**
25	M, Nuclear research	**0.7168**	-0.1042	0.0052
Explained variance		22%	22%	14%

3. Conduct Q-sorts and post-sort qualitative data collection.

Each of the sampled 40-statements were assigned a number and put in a random order. Respondents first sorted the Q-set into three physical piles – into those that they agreed with, those they disagreed and those they were either unsure or neutral on. In the second step, each participant sorted the statements onto a grid (shown in figure 1) according to the provided instructions, namely: those statements that were "most like my perspective" (+4) to those that were "least like my perspective". The centre point of the grid (0) represents a neutral stance. The initial three-pile sort helps to structure this process, but statements can move and be reordered among categories. Though most (20) sorts were conducted in person using a physical pack, 5 used the QSortware™ online programme to conduct the same process where click drag and drop mimics the physical sorting of cards online. Once the sorting grid was filled participants provided written qualitative feedback on the selection of statements at the extreme ends of the grid (+4 and -4) and the sorting pattern overall. The qualitative input was used to help construct the discourses in the final stage of the analysis.

4. Statistical analysis of completed Q-sorts.

Completed Q-sorts were input to an Excel file and analysed using KADE software (Banasick, 2019). First, a correlation matrix of all completed Q-sorts was constructed, and then subject to Principal Components Analysis (PCA) – a data condensation technique for factors that are orthogonal to one another (statistically and linearly independent of one another). PCA combines predictors and drops the eigenvectors that are relatively unimportant, thus providing a structure to the data: illustrating the directions where there is the most variance and then reducing the number of variables by creating linear combinations that retain as much of the original measures' variance as possible (Conway and Huffcutt, 2003).

After analysis of the scree plot of the Eigenvalues of principal components, a three-factor solution was retained and rotated using Varimax rotation. The three-factor solution explains 58% of total variance. Each factor had at least 6 Q-sorts loading on it, and each factor was statistically significant (Eigenvalue >1.00). Q-sorts were individually numbered 1-25. Loadings on factors are shown in bold to illustrate the

defining sorts for that factor – the exemplar sorts that are characteristic of that factor (Watts and Stenner, 2012). All Q-set items, rankings and rotated factors are shown in table 2.

Table 2. Factor scores with corresponding ranks.

		Factor		
No.	**Statement**	**A**	**B**	**C**
1	Communities should have the right to volunteer to host a radioactive waste management facility.	+2	-1	+2
2	Radioactive waste management is a legacy issue from early nuclear power and weapons production. Wastes arising from future nuclear power stations is only a marginal issue.	-1	-3	+3
3	Radioactive waste should be perpetually stored safely on site where it is produced.	-4	0	-2
4	Radioactive wastes from across the country should be disposed of together in a deep geological disposal facility.	+2	0	0
5	A community should have a right to withdraw from a site selection procedure at any point before construction begins.	+1	+1	0
6	Communities should support a geological disposal facility as it will create permanent jobs for the duration of the project.	0	-2	0
7	There should be no expansion of new build nuclear power until a solution is agreed for the final disposal of radioactive wastes.	0	+4	-3
8	If a radioactive waste facility was sited close to my home, I would be concerned about the negative impact upon the value of my property.	+1	+2	-1
9	Communities that host radioactive waste facilities should receive benefits in the form of direct cash payments to residents.	0	-1	0
10	We must prioritise the reduction of health risks from radioactive waste management to “as low as reasonably practicable”, irrespective of cost.	+1	+3	+2
11	The public perceives radioactive waste-related health and environmental risks as much higher than they actually are.	+4	-2	+3
12	We should prioritise a radioactive waste management solution that minimises the transportation of radioactive materials around the country as much as possible.	+2	+1	0
13	We must halt the construction of new build nuclear power in order to minimise the risks associated with radioactive wastes.	-3	+2	-4
14	The assurance of safety by scientific experts is not enough to convince a host community to accept wastes in their locality.	+1	0	-2
15	Communities that host radioactive waste facilities will be stigmatised by outsiders.	-2	+1	-1
16	The presence of radioactive waste facilities will damage tourism in the area where they are sited.	-1	0	-1

17	Radioactive wastes are infrastructures of national significance, and so decisions about their siting should be made by elected representatives in central government.	0	-2	0
18	Plutonium extracted from spent nuclear fuel should be classified as a resource and be used in the creation of fuel for electricity generation.	+1	0	+4
19	The costs associated with radioactive waste management should be minimised as much as possible in order to reduce the burden on the taxpayer.	+1	-2	-2
20	It is unfair that nuclear wastes will harm future generations when they gain no direct benefit from nuclear-powered electricity.	0	+1	-2
21	We should re-open the debate about radioactive waste management to include options other than deep geological disposal in an underground facility.	-2	+3	+1
22	Providing community benefits in return for hosting a facility is state bribery of local people.	-2	-1	-1
23	Public opinion on radioactive waste management is subjective, it should not override the opinions of scientific and engineering experts.	-1	-2	+3
24	I would personally be happy to live within 1 kilometre of a radioactive waste management facility.	0	-3	+1
25	I am confident that the Government will find an acceptable and safe solution to radioactive waste disposal	0	-4	-3
26	Given that the majority of radioactive wastes are stored at existing nuclear power facilities, these should be the first communities to step forward for radioactive waste facility site selection.	-1	-1	-1
27	Burying nuclear wastes underground will put the problem ‘out of sight, out of mind’ with potentially dangerous consequences.	-3	+1	-1
28	The communities that host radioactive waste facilities should be willing to accept the associated risks for the overall benefit of society.	-2	-3	+2
29	I am concerned about the long-term ecological impacts to wildlife and biodiversity from radioactive waste management.	-2	+2	+1
30	We should prioritise the guarding of radioactive waste facilities against sabotage, terrorism or theft of nuclear materials.	+2	+2	+1
31	Building a nuclear waste facility has the potential for the type of disaster seen in the accidents at Fukushima or Chernobyl.	-4	+2	-3
32	I support the renewed expansion of nuclear power in this country.	+3	-4	+4
33	Providing cash or infrastructure incentives to communities to accept waste facilities is unfair, as it will encourage only poorer communities to step forward.	-1	0	0
34	We should classify plutonium as a waste product and dispose of it alongside other radioactive wastes due to its potential use in nuclear weapons production.	-1	0	-4

35	Local councils should make the decisions about radioactive waste facility siting as they represent the interests of local communities.	0	-1	0
36	Burying radioactive wastes is dangerous because we cannot communicate the risks to people alive thousands of years from now in a language that they will understand.	-3	0	-2
37	Finding the safest solution to the radioactive waste management problem is preferable to finding the quickest solution, irrespective of cost.	+2	+3	+1
38	Radioactive waste facilities must be passively safe as we cannot ensure that society will remain political stable and take care of wastes long into the future.	+3	+4	+2
39	Building public trust in the nuclear industry is vital to ensure a safe and acceptable radioactive waste management solution.	+4	-1	+2
40	Public participation should be at the heart of any radioactive waste decision-making process.	+3	+1	+1

5. *Qualitative interpretation of factors into distinct perspectives*

The aggregate Q-sorts were re-interpreted as a distinct shared viewpoint (sometimes called a "perspective" or "discourse"). Each is interpreted through reference to the positioning and configuration of items in the relevant best-estimate factor arrays found in stage 4 of the analysis (Watts and Stenner, 2012). In this case we looked first at the *distinguishing statements* (i.e. statements that were ranked significantly differently between a given factor and all other factors, and the statements that were not ranked differently by any factors, see Webler et al., 2009), followed by all statements at +4 and -4, and then the patterning of all other statements (including those with a neutral value). The meaning and description of the shared perspectives is then shaped and contextualised through reference to qualitative data collected after the sorting process, examining statements made by sorters that loaded on the respective factor under discussion. Crucially, as constructed aggregates these distinct perspectives may not be wholly coherent and might involve what could be seen as contradictions. However, any one individual would struggle to offer complete coherence on any topic; therefore, it is in these contradictions of natural or constructed perspectives that we may learn the limits of a perspective and how competing priorities shape a perspective.

6. *Explore the areas of agreement and disagreement between perspectives.*

Finally, factor interpretation involves consideration of statements which distinguish individual factors from one another (indicative of points of disagreement between stakeholder perspectives), and those statements which do not distinguish between factors (and others indicative of points of agreement or consensus amongst competing stakeholder positions). This step is particularly valuable in normative environmental policy research in order to define routes towards procedurally just planning outcomes that incorporate diverse values and beliefs (Cotton, 2015; Aigbe et al. 2023).

3. Results

The three emergent factors are subject to interpretive analysis in order to turn them into *shared perspectives* emerging from the statistical analysis of 25 Q-sorts (see table 2). These are then connected to broader environmental discourses in the discussion of the quantitative and qualitative data.

Specific Q-statements that contribute to these factors are below referred to in brackets, with the valence of the statements (their relative ranking) listed, e.g. (s12, +3). As is common in Q-method studies, the interpretive analysis of the factor array means that each factor is given a descriptive moniker to capture the essence of the perspective expressed.

The complete list of loadings of each statement relative to the factor is shown in table 2 with factors listed A, B and C. Each of the statements is labelled with an "s" (for statements). Each of the statements defining the factor is statistically significant at a p-value of 0.05. The statements flagged * are statistically significant with a p-value of 0.01. The factors are then subject to interpretive analysis. These are named as:

A. Managing a distrustful public
B. Fair and democratic nuclear waste decision-making.
C. Putting the experts in control

Perspective A – Managing a distrustful public

For proponents of perspective A, the first issue of importance is the relationship between the radioactive waste management organisation (in the UK this is Nuclear Waste Services) and affected publics in the management of risk. This is expressed in strong support for actions that build public trust (s39*, +4) through active citizen participation in decision-making processes (s40*, +3). This support is commonly described as reflecting a 'participatory turn' in radioactive waste management - that stakeholders participating in this Q-sort activity reject technocentric decision-making that prioritises the voices of engineering and other technical expertise over those of affected communities and other stakeholders (s14, +1). Proponents of perspective A believe that communities should not be coerced (through a utilitarian moral stance) to accept wastes on behalf of society, without a say in the process through which waste management is decided (s28*, -2). As participants loading on perspective A stated in the qualitative responses:

You simply cannot force people to accept wastes without their consent.

Though support for a participatory approach is established within this perspective, there is also a contrasting position expressed – that non-specialist heterogeneous publics over-estimate or over-emphasise the environmental risk dimensions of nuclear wastes – in essence proponents believe that the overall perceived risk is greater than the 'actual' hazard that they pose (s11, +4). Perspective A thus calls for 'evidence-based policymaking' that prioritises scientific knowledge within decision-making processes, one which balances risks, costs and benefits proportionally.

Often radioactivity represents a scary unknown concept for people.

> *Public perception of health risks is seriously overstated by media reporting in distorted terms. A more evidence-based viewpoint is not being presented in layman's terms.*
>
> *When we prioritise the reduction of health risks irrespective of cost, we subconsciously drive away critical research funding and techniques with outcomes that can be trusted by scientists the media and the people.*

Linked to this, proponents of A are unconcerned that nuclear wastes could pose the type of high-profile and widely discussed catastrophic public risks, as seen in high profile nuclear disasters at Fukushima or Chernobyl in the last 40 years (S31, -4), nor long-term ecological impacts to biodiversity or ecological health (s29*, -2).

> *There is absolutely no chance of a Fukushima style disaster from a radioactive waste disposal facility.*

There is therefore consonant support for centralised national-scale deep geological disposal (S27*, -3; s4*, +2) as a 'passively safe' solution (s38, +3). A deep GDF is deemed to be a safer alternative to perpetual onsite storage of wastes at source (s3*, -4). There is also little expressed support for re-opening socio-technical debates over the best form of radioactive waste management options overall (s21*, -2) – there is consensus within this perspective that a GDF is the 'best' sociotechnical combination for safe waste management.

> *That debate (over radioactive waste management options) has been had with documented reasons for the outcome. Geological disposal is the safest option long term.*

The second issue concerns the spatial dimensions of different sociotechnical configurations of waste management. Proponents of A acknowledge that radioactive waste management is not solely a legacy issue from previous years (s2*, -1), but conversely radioactive waste production should not be a barrier to new nuclear energy construction (s13*, -3; s7*, 0). Thus, a broadly pro-nuclear power production position (s32, +3) with a utilitarian element is inherent to perspective A, in part as the perceived risks is deemed to be low from nuclear related activities in society.

> *We must not halt the construction of new build plant to minimise risks. Risk perception is highly distorted and subjective and not a basis for policy decisions.*
>
> *Obviously, a personal choice but seeing the benefit of readily available energy underpinning the benefits of modern lifestyles, the difficulty in waste management is small in comparison.*

Support for new nuclear build extends not just to existing use of uranium, but also to plutonium reprocessed from spent fuel and other sources – treating it as a resource (s18*, +1), rather than a waste product (s34*, -1), in contrast to current Government strategy that treats plutonium as requiring a long-term disposition solution that puts it out of reach from human contact (NDA 2019).

The third issue concerns a tension between a desire to provide inclusive social evaluation of nuclear waste management processes and risks, with an underlying sense that waste management is much 'safer' than citizen stakeholders generally believe, and that the current course of action (a centralised GDF) is the normatively 'best' option, in part due to potential tax-payer cost savings of a centralised approach (s19*, +1).

> *A single repository is essential, rather than scattered wastes with variable accessibility. The chances of finding multiple locations with good geology and public acceptance at the same time are too slim.*

Thus, proponents of A primarily see the waste challenge on two geographic and governance scales. At one scale, is the challenge of resolving a socially constructed risk perception 'gap' at a national scale between lay public and specialist perceptions of the risks involved as a means to gain social acceptance for 'safe' current technical solutions (s32, +2), whilst remaining mindful of local-scale coercive practices that would produce social harms to communities (not least impacts on local property values: s8*, +1, or disempowerment of community decision making: s1, +2; s5, +1). It is notable that although there is support for community engagement and empowerment in decision-making there is a very neutral stance taken on the type of decision-making framework that should be implemented, the timescales and intergenerational risks and benefits that might occur (s20*, 0), and specifically on whether either central government (s25*, 0), or local government (s35, 0) would be best placed to manage these processes of decision-making.

> *I'm not confident that a politically led process will result in finding successful solutions to waste disposal. The government should support evidence-based decision making: the science, technology, socioeconomic and implementation dimensions of the preferred solution.*

As such support for perspective A reveals a need to explore further the desired governance structure for waste management to ensure the balance of risks, social impacts, community acceptance and safety, but little sense of which branch of government is best placed to do this. Thus, we argue that this perspective is associated with Hadjilambrinos' (1990) *pragmatic utilitarian* discourse. Proponents of perspective A recognise the political expediency of engaging with heterogeneous publics and accepts that concerns raised by community members present a barrier to GDF siting progress. However, proponents of perspective A also posit these concerns as 'subjective' and 'distorted', with the implication that supplying the correct information or following 'evidence-based' policy will mitigate misunderstanding and consequently grow public support. This we might term a *contextualised deficit model* through which subjective positions are recognised as important to policymaking but are still deemed inferior to the objective positions of technical experts.

Perspective B - Fair and democratic nuclear waste decision-making

Perspective B is defined as a clearly expressed anti-nuclear position. Proponents of this position argue for the halting of new build nuclear power expansion (s13*, +2; 32, +4), and view waste and nuclear build as intertwined contemporary environmental

governance concerns, rather than as a legacy issue for the nuclear industry and society (s2*, -3). Opposition to new nuclear build is therefore driven primarily through a desire to reduce the risks associated with radioactive waste management (s7*, +4).

> *I think we're on the wrong trajectory with electricity supply and think there are more environmentally acceptable solutions to our base level energy needs, for example tidal energy, or water storage.*

The reasons for opposing nuclear power and its inherent link to radioactive waste risks are broad in scope. Proponents of B point to wide-ranging impacts upon the natural environment and human societies. There is significant expressed concern over the *dread risk* of nuclear catastrophe (s31*, +2) (see for example Sjöberg, 2003), shaped by high profile nuclear disasters reported at Fukushima and Chernobyl in recent decades. There is also concern that the negative impacts of radioactive waste management will lead to long term negative ecological, socio-economic and sociocultural impacts to wildlife (s29*, +2), the stigmatisation of waste-hosting communities (s15*, +1), and to negative impacts upon homeowner property values (s8*, +2), meaning that proponents of perspective B would not wish to live close to a radioactive waste management facility (s24*, -3). As the qualitative comments show:

> *The ecological and class impacts are my main priorities.*

> *I think it is really important that health and safety is paramount and that all communities have a voice in the process.*

Proponents of B do not think of public risk concerns over a long-term radioactive waste solution as alarmist or over-emphasised (s11*, -2). Rather they remain concerned that disposal solutions might minimise public knowledge of the risks of wastes to the biosphere and to communities on the surface (s27*, +1), including risks of the misuse of radioactive waste materials in the future (s30, +2). Given concern for these risks, proponents of this perspective prioritise *passive* safety solutions (s38, +4), guided by the as-low-as-reasonably-practicable (ALARP) principle of risk management (s10, +3), irrespective of public financial cost (s37, +3), or indeed for communities to volunteer to host waste facilities (s1, -1). Together these positions are indicative of support for The Precautionary Principle – that safety is the ultimate priority, irrespective of financial cost. As these proponents stated in the qualitative comments this is:

> *Because health issues matter the most.*

> *The safety of the people come first.*

It is notable however, that there is hesitancy or uncertainty over the best solution to achieve this passive safety. Proponents of B remain neutral on some of the core technical and safety debates within the nuclear waste policy domain – specifically the issue of deep geological disposal-vs-perpetual above ground storage (s3, 0; s4, 0), or the classification of plutonium as a resource or waste product (s34, 0; s18, 0). This hesitancy or uncertainty is likely, as some participants loading on this perspective stated, because:

I felt unable to agree/disagree on many of the statements as I am aware of my own ignorance around this subject.

I am not an expert in the field therefore I am stating my mere opinion; while completing this sort I realised how little I know about this critical issue.

The Q-sorting process therefore highlights some of the difficulties of gauging social and ethical value perspectives on complex technical debates when those values are expressed in what is sometimes termed a 'low information environment' (Jerit et al, 2006). Thus, further engagement on these dimensions is likely needed in public discourse on the issues, with proponents calling for a reopening of the radioactive waste management options debate to further public scrutiny (s21, +3).

Though less confident in expressing a position on some of the core technical arguments, anti-nuclear proponents do strongly express concern for the environmental justice dimensions of radioactive waste management. This perspective expresses concern about marginalised or voiceless communities in decision-making processes. These include economically and socially vulnerable communities as well as future generations (s20, +1).

Analysis suggests that it is always the poorest and most marginalised that suffer most from environmental injustice.

Ameliorating environmental distributive environmental injustices from the uneven distribution of risks and benefits across geographies and temporal horizons requires participatory mechanisms of community involvement (s40, +1). There is a strong rejection of the 'decide-announce-defend' or 'technocratic' model of decision-making (s23, -2) – alongside rejection of the utilitarian stance that communities should be willing to accept risks on behalf of society (s28*, -3). As such there is modest support for voluntarist models of decision-making in which communities have a right to withdraw from negotiations (s5, +1).

There is some support for community benefit mechanisms as compensation for the risks of hosting a waste facility (s22, -1), though compensation in the form of job creation was not supported (s6*, -2).

No community should have to bear the consequences without benefits.

The obsession with jobs by the Government is cyclical and not realistic. I doubt these new jobs would go the community anyway. Also, communities don't always want to work where they live.

There is also a rejection of aggregative or representative democratic models of decision-making. This involves little support for national infrastructure bodies or elected representatives to make siting decisions (s17*, -2), due to a fundamental lack of trust in central or local governmental authorities to find a safe and acceptable solution (s25, -4; s35, -1). This position also has a concern that activities in trust building in the nuclear industry are detrimental to societal vigilance (Lehtonen et al, 2021a; Lehtonen et al, 2021b; Meyer, 2022).

The government doesn't make these complex decisions on its own. It is always swayed by vested interests and lobbying.

I have significant concern and cynicism regarding the decisions of central and local government.

Thus, we associate perspective B with the discourses of *peripheralisation* and *environmental justice*. We see elements of peripheralization in the statements about the class impacts and marginalised communities. However, this also links to *eco-centric* ethics, specifically the ecological and wildlife impacts of nuclear power and waste. We could see therefore a nascent *political ecology* discourse – proponents of perspective B links class, power and the means of production to fair outcomes for the natural environment, and the co-production of environmental justice to achieve positive outcomes for both human and non-human welfare.

Perspective C – Putting the experts in control

The closure of the UK's Thermal Oxide Reprocessing Plant (THORP) B205, located in Sellafield in England, brought an end to current plutonium separation from spent nuclear fuel. The UK does not currently utilise plutonium as a fuel for electricity generation, and with excess plutonium to military needs, the Government has amassed a stockpile of almost 140 metric tons of separated reactor-grade plutonium (Fichtlscherer et al, 2020). The practical and ethical dimensions of plutonium stockpiling and classification are points of contention within technical and policy circles, with some arguing for the disposal of plutonium as stream alongside high-level waste, and others arguing for a dual track strategy that converts some to mixed oxide fuel as needed, and the rest immobilised and treated as waste for disposal (Hyatt, 2017). Perspective C is characterised by clear support for this latter approach, whereby the reprocessing and utilisation of plutonium as a fuel resource for electricity generation is deemed a policy priority (s18, +4; s34, -4). This support particularly aims to further new nuclear build, reduce the waste burden and provide low-carbon energy, as participants loading on factor C state:

Throwing away plutonium, such a potent energy source, is expensive and fundamentally stupid.

Classing plutonium as a waste "for safety reasons" is short-sighted and ignorant of its potential for civil use.

Against the backdrop of a pro-plutonium as civilian nuclear fuel stance, is the strong support for new nuclear build (s13*, -4; s7*, -3), and that (s2*, +3) the radioactive waste management issue is primarily a legacy concern from previous generations of nuclear power, rather than a challenge for new nuclear build. This support is also framed as a necessary aspect of dealing with the climate crisis:

The new generation of reactors incorporate the waste management lessons learnt from the legacy waste. There is a learning curve.

Nuclear is a safe and clean energy source.

> *Nuclear fission is the only credible technology to generate large quantities of CO2 free power.*

Alongside a pro-nuclear stance, perspective C is characterised by a support for technocratic, expert-led radioactive waste management solutions focus upon a centralised deep geological disposal solution (s27*, -1) rather than perpetual onsite storage (s3*, -2).

> *The problem with long-term aboveground storage is that for some of these waste types, we need to be able to physically isolate them from human intrusion over very long timescales.*

There is some support for a public engagement model as being necessary for decision-making over site selection (s1, +2; s40, +1) and public trust in the nuclear industry is recognised as a key element of waste siting success (s39*, +2). However, counter to this, public opinion is deemed to be subjective and thus subordinate to expert judgement (s23*, +3) as:

> *I've worked on radioactive waste long enough to know that people are generally not informed enough about the real risks.*

> *While public perception matters, the best decisions will come from experts. For example, public perception on global warming, tends to say it's not real. That does not make it correct.*

Like perspective A there is support for deficit model thinking, in which confidence is expressed in the capacity of experts to assure safety to host communities and thus build public support (s14*, -2). Once they are convinced of the safety of technical solutions to waste management through deep geological disposal, communities are then obliged to accept a moral responsibility to host waste facilities for the good of society overall (s28*, +2), even if that means an unfair distribution of risks and benefits for future generations (s20*, -2). Against this approach is a sense that the problem of waste is a fundamentally *political* rather than *technical* challenge, as reflected in the qualitative statements, some of which express frustration at the lack of progress in the field:

> *We know how to deal with radioactive waste. We've been stopped from finishing the job.*

Yet, despite this frustration there is no expressed position on the appropriate scale of government, either central or local authorities (s17, 0; s35, 0), community rights (s5, 0), nor appropriate mechanisms to compensate or incentivise communities through payments, infrastructure, or jobs (s6, 0; s9, 0). Therefore, resolution of the political challenges of wastes is not easily defined within this perspective.

We associate this position with Hadjilambrinos' (1990) strong utilitarian and technocratic stance. We see this with the statement that the 'best decisions come from experts', the claim that nuclear waste solutions are essentially already resolved, and that implementation of a solution has been stymied by political rather than technical challenges. Mobilising the *deficit model* of public science communication, this

perspective presents an uninformed public as the key barrier to siting progress. The discursive move collapses this public into a monolith while also mischaracterising 'it', as seen in the problematic claim that this public does not believe in the climate crisis and so should not be trusted. This technocratic mindset is where this position also involves elements of Promethean discourse. The categorical claim that "we know how" to fix a solution up to and over a million years is what Nader (2004) might label unscientific statements coming from nuclear scientists. Imagining that this GDF will remain safe over such vast time scales and with interacting social and environmental systems weighing down on it, takes an element of Promethean hubris (Ialenti, 2020; Ramana, 2020) as discussed below.

3.1 Points of agreement

Across the three shared perspectives are a range of key points of agreement or tentative consensus. These points of consensus are indicative of issues that would likely cause the least friction amongst competing stakeholder groups, thus represent 'quick wins' for policy authorities looking to make progress towards the search for a host community and suitable site for a GDF. We identify three primary areas of agreement, based upon the rank ordering of statements by *z-score* amongst those that do not distinguish between factors (indicating agreement across perspectives). These three issues principally concern:

1. **Site safety** – there is agreement that any radioactive waste management solution must prioritise safety over speed of decision-making (s37, A +2, B, +3, C +1). Safety planning should prioritise action that guards against both the threat posed by actors seeking to use radioactive wastes for nefarious means (s30, A +2, B +2, C +1), and also passive measures to ensure safety long into the future under conditions of more generalised political insecurity over the timeframes of radioactive decay within the facility. Such safety measures should follow the as-low-as-reasonably-practicable (ALARP) principle of risk management (s1-, A+1, B+3, C+1).
2. **Community benefits** – interestingly, oppositions remain relatively neutral on the issue of community benefits for hosting radioactive waste management facility both in terms of the format of the payments offered (s9, A 0, B -1, C 0), and in terms of the issue of poorer communities being asked to accept a waste facility in return for benefits (s33, A -1, B 0, C 0). Notably there is universal disagreement that such benefit payments would constitute a form of bribery (s22, A -2, B -1, C -1). However, it is the *how* and *what* of these benefits that are contested on the ground in communities in Cumbria (WCMNWSP, 2012), and GOTEC (2024) in Lincolnshire where such hosting decisions are taken in practice.
3. **Community decision-making and a right to withdraw** – specifically, that the stakeholder participants remain broadly positive or neutral around the community's right to withdraw (effectively a veto) from site selection process up until the point at which construction begins, and that decision-making should be voluntary (s5, A +1, B, +1, C 0), that existing nuclear communities living close to nuclear power facilities should not be the first choice for a GDF site (s26, A-1, B -1, C-1), and that there was hesitancy at recommending local authorities be the partner organisation that negotiates on the community's behalf. It is important here to link this hesitancy to previous studies (Bickerstaff, 2012) and

reports (WCMNWSP, 2012) of communities, and current social groups (GOTEC, 2024) involved in nuclear waste. All these communities also emphasise a distinct distrust of the current democratic arrangements regarding nuclear waste solutions. This implies two things, the first being that representative democratic arrangements are not suitable in a situation where the aggregate society places a cost and risk on marginalised or peripheral section of that society (Cotton, 2017). This seems to be implicitly accepted by the current voluntarist policy approach, with the caveat that the Government could revert to a top-down approach. The second implication is a more general problem in the British polity, with experts and wider society alike seeing politicians and politics as untrustworthy and dysfunctional (Gold, 2023: Quilter-Pinner et al, 2021).

3.2: Points of disagreement

Similarly, points of disagreement are defined by the greatest differentiation between factors, based upon *z-scores* for distinguishing statements. These main points of disagreement concern:

The status of future nuclear power

The first major difference regards support or opposition for nuclear power as a future electricity source (s32: A+3, B-4, C +4; s13: A -3, B +2, C -4). Factor A and C are strong in support for nuclear power, with a proponent of perspective A claiming we 'must' build more nuclear power stations, and another making the utilitarian argument that the greater good to 'modern lifestyle' outweighs the problem of nuclear waste. Perspective C makes similar categorical but more expansive claims, with proponents arguing nuclear power is 'safe', 'clean' and the 'only credible technology' to deal with the CEC. In addition, perspective A and more emphatically perspective C advocate the reuse of plutonium as a nuclear fuel and see current policy treating it as waste as misguided. In contrast, proponents of perspective B in opposing nuclear power argue that there are alternative technologies for producing what is sometimes referred to as baseload energy generation. They also point towards the energy injustices that surround big energy infrastructure, arguing that it is lower class marginalised communities that suffer the burdens at the local level, while politicians and policy are swayed by 'lobbying' and 'vested interests.

Public perceptions and nuclear decision-making

The second major difference expressed between the positions is the *how* of the nuclear waste solutions. Perspective A calls for the GDF and deliberative processes to 'listen' to people's concerns even if these are 'distorted'. This position also calls for a voluntary process although this should be 'evidence-based' not 'subjective', dismissing fears that catastrophic risks would befall a GDF (s31: A -4, B +2, C-3)., and that public perceptions of risk are higher than an objective reality of the hazard that they present (s11: A+4, B -2, C +3). Perspective C asserts that experts should be at the centre of GDF decision processes and is the only perspective that argues for communities to take a moral responsibility for elevated risks on behalf of society (s28, A-2, B -3, C+2). The claim that experts should control decision-making processes partially contradicts perspective C's neutrality on community right to withdraw, as does the statement that communities have a moral duty to accept the elevated risks for the rest of society. This contradiction will be explored in the discussion. Perspective B

asserts a more precautionary principle, a principle that both perspective A and C implicitly reject. Thus, in summary the results of the Q-method show the difference between what we refer simply categorise as a top-down (C), semi-top-down (A) and bottom-up (B) approach to nuclear waste management.

Ecological justice

A final difference to mention regards what Page (2007) refers to as the scope of justice, or the subjects we are considering when talking about justice. there is a distinct anthropocentrism coming from both perspectives A and C which tend to consider human-centred risks when considering the impacts of nuclear waste (s29, A -2, B +2, C +1), whereas proponents of perspective B reference to 'ecological' impacts, and more broadly the Precautionary Principle. This has the potential for consideration of more-than-human welfare in ethically contentious nuclear waste decision-making.

These key areas of environmental discourse concerning nuclear futures, the role of publics and the balance of risk, ethics and consideration between human and non-human welfare are key areas of discursive divergence and potential stakeholder conflict as discussed below.

4: Discussion

4.1: Competing perspectives and environmental Discourses

The broader environmental discourses these micro-discourses suggest were discussed in general above in section 2.1. In this section we will connect these environmental discourses more specifically to the three factors and consider the implications of these discursive links for nuclear waste solutions in the UK. Each perspective is connected to the broader discourse below and will be considered in turn:

A. Managing a distrustful public – links to a discourse of *Pragmatic Utilitarianism*
B. Fair and democratic nuclear waste decision-making – links to a discourse of *Procedural Environmental Justice, and Peripheralisation*
C. Putting the experts in control – links to a discourse of *Prometheanism*

Perspective A links to a normative discourse grounded in utilitarian ethics. It takes a certain scientism with the international failure of top-down nuclear waste governance to maintain that experts should still make all the major decisions. Practically, to make some form of progress there had to be some form of deliberation, as was recognised by perspective A and the overall CoRWM process. However, an essence of utilitarianism is that the ends justify the means, as the branch of utilitarian philosophy *consequentialism* encapsulates. For perspective A, deliberation was a means to the end of both a GDF and more nuclear power. This was suggested by the deployment of the deficit model, which frames a monolithic and broadly ignorant public that works in a subjective mode while experts work in objective mode. This rather simplistic world of a subjective and ignorant public led to the greater good by those who objectively know better is also central to utilitarianism. This perspective accepts the public has differing values and ideas, as Hadjilambrinos (1990) says, it's just that these values

and ideas must be corrected for the greater good, or at least listened to then quietly ignored.

Presenting a view of class-ordered society and concern for ecological impacts of nuclear waste, perspective B connects to both environmental justice and peripheralization discourses. Rather than presenting the public as some monolithic, unified, and broadly ignorant entity, this perspective sees this as divided by class and thus relative power, with those with power able to lobby, defend and reinforce their vested interests. This corresponds with the work of environmental justice scholars, including Voyles (2015) and Gómez (2022), who examine how the nuclear industry in the USA has used its vested interests to load costs and risks on racialised and lower-class communities. These scholars also detail the environmental degradation, or in Voyles' (2015) term "wastelanding", that accompanies the nuclear industry in all its stages. We connect the wastelanding concept with perspective B proponents' ecological concern. This corresponds with aspects of peripheralization, which as detailed above in section 2.1, conceptually focuses upon environmental degradation, political powerlessness, and a more general economic and geographical marginalisation (Blowers, 2020). Finally, perspective B accepts uncertainty with its proponents admitting they are not sure about various aspects of nuclear waste. This could be associated with those loading on this perspective being predominantly non-nuclear industry stakeholders. However, proponents of perspective B also use terms like 'I think' or 'research suggests' more generally than the language of the other two perspectives. Overall, this aligns with the precautionary principle which accepts that in/actions and technologies always have unintended and unanticipated consequences, and that safety (broadly defined to include environmental impacts) should be a high priority.

The Promethean discourse claims control over the Earth and stakes a claim to how we know this Earth through a very quantified mode of knowing. Perspective C evokes this discourse through strong support for the use of plutonium, the claim that nuclear is the 'only credible technology' to deal with the climate crisis, and technocratic positions on nuclear waste decision-making. Promethean discourse is one of *control* – yet as many environmental scholars consider – such control is perhaps more the ability to damage and unbalance natural systems (Vettese & Pendergrass, 2022; Dryzek & Pickering, 2019). Perspective C expresses technocentric control of nuclear technologies through scientific certainty, excluding other forms of knowledge (Overoye & Storm, 2015), including lay expertise (Skarlatidou et al., 2012). This would also fit with what science ostensibly is, *accurate until proven otherwise*, and thus an exploration of a fundamental and ongoing uncertainty (Peat, 2002). Perspective C, and to a lesser extent A, with their categorical claims, are a little too certain for even this basic notion of science.

Proponents of perspective C express an internal contradiction that speaks of the Promethean discursive construction of technological control. While this perspective is neutral on a community right to withdraw from the process, the strong loading on statements that assert *expert involvement* in technology decision-making, and qualitative statements concerning how host communities have a moral duty to take on the elevated risks for society are strong indicators of utilitarian and technocratic sociotechnical configurations of the waste problem. Contradictions are expected within aggregated perspectives from the factor analysis, (and indeed within individual sorts

themselves), though we can speculate on this particular contradiction. Firstly, the expressed neutrality could be connected to the fact community right of withdrawal is current policy and positivist perspectives like C tend to conflate what is with what ought to be, especially in terms of what is politically feasible. However, as both perspective A and C frame this public and community as possessing a knowledge deficit and therefore are acting contrary to rational decision-making bounded by scientific and technical expertise. This neutrality is thus likely conditional upon a sense that experts should *lead* deliberative processes, and thus have control over what types of social and ethical factors are relevant to decision-making.

4.2: Policy recommendations

We define three principal policy recommendations stemming from this Q-method analysis of stakeholder-derived environmental discourses.

First, a community right of withdrawal (sometimes called a 'veto') should be seen as a core component of the waste policy design, as well as important in balancing local (site-specific) and regional community interests. The search for a GDF is broadly supported as a desirable sociotechnical configuration by all participants within this study. However, the aims of this search could be reoriented by reframing the right of community withdrawal as both an example of procedural justice (rather than a 'failed policy') and an opportunity for policy learning and democratic renewal. Previous experiences in the UK where GDF siting has 'failed', most recently in West Cumbria, showed how community concerns expressed at a regional level were expressed via the lower tier of government (the borough councils). The learning here, is to find mechanisms to balance local and regional interests, and to provide parity between them in decision-making processes (Cotton 2018). By contrast, the government has prioritised explicitly *local* values and perspectives in decision-making. Though this has potentially benefits for local environmental justice related to waste siting, it risks pitting one local community against another, as seen currently in community tensions embodied in relationships within and between relationships the Guardians of the East Coast (GOTEC) organisation in Lincolnshire and South Holderness Action Group in Humberside (Maslin, 2024).

Second, plans for new nuclear build in the UK will complicate the search for the GDF as well as present new risk profiles requiring new and independent risk analyses. The government's new announcement of 24 GW of nuclear energy (GOV.UK, 2024) complicates the national search for a GDF. This is because this expands the GDF inventory beyond the lower and higher range previously published (NDA, 2022), of which both GOTEC (2024) and Cumbrian stakeholders (WCMRWSP, 2012) expressed concern. The UK Government announcement of financial and practical support to new nuclear build nationally also includes new technologies Small Modular Reactors (SMR) and Advanced Modular Reactors (AMR). New technologies involve new risk profiles and there is some speculation that the waste produced from these new reactors may be more fissile and not suitable for current GDF designs (Krall et al, 2022). An ethical nuclear future requires deep consideration of these potential future risks of technological and waste incompatibility, given high-stakes and high-cost of an intergenerational GDF project, consonant with the Precautionary Principle.

Third, deliberation should be expanded from dealing with nuclear waste to broader decision-making on collective energy futures, if a just transition is to be achieved. The CoRWM-led deliberative process on nuclear waste options at a national scale was not repeated for nuclear power expansion in the context of other energy technology options. Adopting such a strong deliberative democratic exercise towards new nuclear futures, first promised by the Labour government in 2003 (DTI, 2003, p. 12), never materialised (Johnstone, 2010; Geels, 2014). Such a deliberative process on holistic energy futures modelled on the CoRWM processes would extend the range of choices surrounding the decarbonisation of our wider energy system and associated injustices (Nolden et al, 2022; Bayliss et al, 2021) and would build just transition planning within a new industrial strategy for energy supply. Recent experiences in the UK of the Citizens' Climate Assembly, and regional level Climate Citizens' Juries, alongside international experience of more specialised Nuclear Citizen's Juries (in Southern Australia) (Calyx and Jessup, 2019) and associated assessments of their relative efficacy and contribution to environmental justice (see for instance: Reedy et al. 2023; Ross et al. 2021) would be instrumental in designing this new approach. By deliberating energy futures, this could rebuild public trust and engagement in democratic decision-making, given that all participants in this study viewed existing policy engagement processes with scepticism.

5: Conclusions and policy recommendations

This paper used a Q-method approach to examine nuclear discourse in the UK at a time when policy around both nuclear power and waste are sociotechnical configurations in flux. It found three factors, or shared perspectives, revealing strong stakeholder disagreement between industry and non-industry stakeholder actors on the nature of the problem and the normative dimensions of its solutions. What is notable is the 'stickiness' of such stakeholder conflicts in the nuclear policy space. On the one hand, we have stakeholders still strongly in favour of nuclear power and insisting upon deficit model of science communication to build public trust – an issue problematised by Wynne more than 30 years ago (Wynne, 1989; 2014). On the other hand, we have those that oppose nuclear power. Such opposition focuses on issues of excessive infrastructural cost and socio-environmental risks falling unjustly upon marginalised communities and the non-human environment. They also question the legitimacy of power and vested interests within the industry more broadly. From our findings we argue that hope towards stakeholder consensus and the development of desirable nuclear sociotechnical configurations must be found by discursively reframing nuclear waste policy in terms of community and ecological safety and community fairness, with those opposing nuclear power still open to debating the nuclear waste issue fairly (i.e. not using opposition to waste *instrumentally* to block new nuclear build).

These findings present both challenges and opportunities. As stated above, the UK government's announcement of a significant expansion of nuclear power potentially complicates the process of finding a host site for a GDF. We argue that more widespread opposition is likely to emerge to the policy of new nuclear power. We suggest that energy policy on nuclear new build cannot be made in isolation from other technology choices (including renewable and other alternative energy production systems); nor can it be made in isolation from the GDF site selection process. Broader

public deliberation on the scale of CoRWM's options assessment process and recent National Assembly-level deliberations under the ongoing Managing Radioactive Waste Safely policy platform would serve to address the many injustices emergent without the UK's energy system. It would also present new opportunities for infrastructure planners driven by urgency, to consider the deeper considerations of voluntarism, community benefit, environmental justice, and ecological impact, thus potentially transforming the sociotechnical configurations of nuclear and non-nuclear infrastructure planning futures.

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