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Appraising sociotechnical visions of sustainable energy futures: A distributed deliberative mapping approach

Rob Bellamy [a,*], Jason Chilvers [b], Helen Pallett [b], Tom Hargreaves [b]

[a] *Department of Geography, University of Manchester, Oxford Road, Manchester M13 9PL, United Kingdom*
[b] *Science, Society and Sustainability Research Group (3S), School of Environmental Sciences, University of East Anglia, Norwich Research Park, Norwich NR4 7TJ, United Kingdom*

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A B S T R A C T

Meeting international targets to limit climate change requires countries around the world to decarbonise whole energy systems. It is increasingly recognised that low-carbon energy transitions will need to focus as much on social transformations and the meaningful engagement of society as they do technical aspects. Most existing studies to engage society with energy system change focus on discrete forms of participation around specific technologies or particular parts of the energy system, with very few exploring distributed engagements with energy in terms of 'whole system' change. We set out to address this research gap in two important ways. First, we report on an innovative approach to opening up diverse issue framings and participant perspectives about energy futures in the UK, called distributed deliberative mapping (DDM), that examines how alternative formats and models of public participation shape appraisal outcomes. In this way, we experimentally broaden out beyond conventional deliberative formats of participation, in terms of 'representative' mini-publics and expert elicitation, to also engage with activist, grassroots innovator and consumer-based models of participation and their associated publics. Second, in doing so we develop an explicitly sociotechnical approach, emphasising the often-unacknowledged social arrangements that are co-produced with the technical elements of energy systems. Six diverse sociotechnical visions were developed and appraised: business as usual, large-scale technologies, deliberative energy society, smart tech society, local energy partnerships and off-grid energy communities. Across the five groups, we find a variety of problem framings that go far beyond the energy 'trilemma' and a greater diversity and range of technical and social criteria with which low-carbon energy futures are appraised. Our DDM study involving citizens and specialists shows that incumbent visions of centralised energy systems, such as business as usual and large-scale technologies, perform much lower than decentralised alternatives, such as a smart-tech society and local energy partnerships. Rather than a dominant focus on eliciting the views of 'representative' mini-publics to inform centralised decisions made by those managing 'the transition', DDM reveals and can support much more distributed modes of governing and democratising sustainable energy futures, across spaces and scales.

1. Introduction

Countries around the world have initiated processes to significantly reduce greenhouse gas emissions in addressing climate change [1]. Meeting these targets will require extensive decarbonisation of whole energy systems, with far reaching implications for energy demand, supply and distribution. While the emphasis in energy research and policy has been on technical aspects of the problem [2], it is increasingly recognised that realising low-carbon energy transitions will necessarily be accompanied by wide ranging social transformations and depend on the meaningful engagement of society [3]. Social studies of science and innovation have shown that scientific, technical, economic and policy commitments to decarbonisation will always co-produce imagined, actual and often unacknowledged social futures – in terms of how transitions are governed, socially organised, include/exclude publics, and lead to (in)equalities in the distribution of risk and benefits [4–6]. Increasing awareness of societal dimensions of energy transitions has been accompanied by concerted efforts in societal engagement: to elicit

; DDM, Distributed Deliberative Mapping.

* Corresponding author.
E-mail address: rob.bellamy@manchester.ac.uk (R. Bellamy).

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public views on the direction of technological and policy change [7,8], shifting energy-related practices and behaviours in everyday life [9,10], or through more 'bottom-up' grassroots innovation and action [11].

In this context, most existing studies and initiatives to engage society in energy system change focus on specific technologies or attend to particular parts of the energy system – for example nuclear technologies, renewables, and carbon capture and storage on the supply side [12–14], pricing, economic incentives and smart meters on the supply side [15,16], and power lines and smart grids on the distribution side [17,18]. Very few studies have explored public views on energy in terms of 'whole system' change. An important exception is one exploring public views on UK energy system change through a representative national survey coupled with deliberative discussion groups [7,19,20]. In this paper we build on and go beyond these developments in two important ways. First, we report on an innovative distributed deliberative mapping (DDM) approach which not only seeks to open up to diverse issue framings and participant perspectives on energy system change, but goes further in examining how alternative formats and models of participation shape appraisal outcomes. Second, in doing so we take a more explicitly *socio*-technical approach, attending to social dimensions and social futures that often go unacknowledged when making scenarios and visions of energy system transitions public.

Engaging citizens through different forms of deliberation is now common practice in the energy social sciences as it is seen to open up problem framings, actor roles and positions, and thus to bolster recognition of public voices and values in decision-making fora [21–23]. The DDM approach presented in this paper, however, advances on existing deliberative approaches to public engagement through deliberately attending to the powerful role that the actual practice, model or 'technology' of participation plays in shaping participating actors (e.g. publics) and their views on the object in question (i.e. energy system futures) [24–26]. Viewed from this more relational and co-productionist perspective, the aforementioned studies on public views of energy system change adhere to a relatively narrow range of formats or 'atmospheres' (cf. Latour and Weibel [27]) of participation, mainly limited to reproducing surveys of statistically representative social wholes or more qualitative forms of engagement centred on mini-publics and informed by deliberative democratic ideals of discursive ethics. A comparative study by Chilvers and Longhurst [28] shows how diverse practices and models of participation with energy systems – which goes beyond professionally facilitated deliberation to analyse diverse cases of household behaviour change, autonomous activism, and grassroots innovation – each co-produce different public identities and contrasting visions of energy futures. Chilvers, Pallett and Hargreaves [29–31] have taken this thinking to map a wider diversity of 258 cases of public engagement with UK energy transitions, which confirms how the configuration of practices through which publics engage with energy is important in shaping how they view and act on energy transitions. The first advance of the study reported on in this paper compared to existing participatory appraisals of whole system energy futures, then, is to make different models of participation a key comparative experimental focus for the first time in the energy field.

Existing work on energy futures and energy system change is dominated by quantitative and modelling based approaches in engineering, physical sciences and economics, with an emphasis on technical assessments of carbon reduction potential, security and costs of contending energy mixes and transition pathways [32–34]. More recent work – much of it in this journal (see for example vol.35 on 'Energy and the Future') – has done much to develop more socio-cultural [35], community-led [36] and place-based [37] approaches to energy futures that emphasise their cosmopolitan, dynamic and contested nature [38]. Nonetheless, attempts to engage wider society in appraisals of energy system change have too often been drawn to taking the scenarios and imagined futures of models and technical assessments as objects for public engagement (e.g. Trutnevyte et al. [39]; Upham et al. [40]; Demski et al. [41]). For example, Demski et al. [41] engaged publics in workshop discussions using the my2050 scenario-building tool where participants selected a mix of supply and demand options under three scenario narratives (no change, high-technology and low-carbon living). In the current study, we sought to develop a more explicitly socio-technical approach through foregrounding the alternative social dimensions of energy transitions that are always co-produced with technological and policy commitments [3,5,6,42] – including alternative modes of governing, equity, models of growth, and the roles of society. A second key contribution of our approach, then, is how it seeks to pay greater attention to the social futures and dimensions of energy system change in how participation and appraisal processes are framed.

This paper forms part of a study developing a wider systemic approach to mapping participation with low-carbon energy transitions that combines DDM with comparative case mapping of diverse public engagements across energy systems. The broader approach and high-level synthesis of these two methods is reported elsewhere (see [30]), but it is in this paper that we report the full DDM method, its in-depth findings and its implications as an approach to engagement in its own right. In what follows we begin by describing how we further developed the established method of deliberative mapping through opening it up to a distributed range of alternative and already existing models of participation in the UK energy system. We then report on our analysis of the social appraisals in the DDM process, including how the different publics framed the problem of sustainable energy futures, the criteria they developed with which to appraise those futures and how they weighted them, how they scored the performance of the energy futures against those criteria, and what the overall patterns of vision performance were. We end by discussing our results in relation to other studies, reflecting on the performance of the DDM method, and examining the significance of our findings for governing sustainable energy futures as distributed sociotechnical systems.

2. Methods: opening up deliberative mapping

Deliberative mapping is an established analytic-deliberative method that combines the strengths of quantitative decision analysis and qualitative participatory deliberation to appraise alternative courses of action in complex and contested issues [43]. It engages both specialists and citizens in a participatory multi-criteria analysis process that sees participants: (1) frame the issue under consideration, (2) select and define options to appraise, (3) characterise a set of criteria against which to appraise those options, (4) score the performance of the options against those criteria under optimistic and pessimistic assumptions, and (5) assign weightings to the criteria to indicate their relative importance. The method yields quantitative maps of option performance under uncertainty and ambiguity that are, crucially, underpinned by in-depth qualitative reasonings. The method has been developed and applied across a wide range of complex and contested issues, including how to address organ transplant shortages [44], radioactive waste disposal [45], dementia prevention [46] and anthropogenic climate change [47].

The deliberative mapping method is virtually unmatched in its capacity to systematically broaden out and open up objects of participatory appraisal and how they are framed [48]. However, it has not yet fully extended this powerful capacity for reflexivity to its subjects of participation or its model of participation [26]. Importantly, like many contemporary methods of public participation, deliberative mapping adheres to a deliberative democratic model of participation in which alternative formats or 'atmospheres' [27] of democracy are unaccounted for. Recognising that deliberative methods actively configure social and power relations and thus serve to (re)produce particular social realities [49], we sought explicitly to experiment with the deliberative mapping method in the current study by taking a more distributed approach, intentionally opening the method up to diverse models of participation and associated energy publics. Rather than seeking to configure alternative models of participation in laboratory like settings, as recently undertaken by Bellamy, Lezaun & Palmer [50] in the context of geoengineering, we sought to enact deliberative mapping in pre-existing collectives, with their own distinct already established models of participation. In their comparative case analysis of energy participation, Chilvers & Longhurst [28] identify four such models of participation and associated subjects: (i) deliberative citizens in professionally facilitated deliberation; (ii) consumer citizens enrolled in a market-based behaviour change model of participation; (iii) activist citizens with an autonomous-horizontal model of participation; and (iv) innovative citizens with a community-based grassroots innovation model of participation. These four models and the distinctions between them were also strongly reflected in a UK-wide mapping of 258 diverse cases of participation in and around low carbon energy transitions which was linked to the DDM process (see [30]). This mapping informed the design of the DDM process and further justified the use of these four models of participation as a basis to identify already existing groups to be involved in the study.

2.1. Sociotechnical visions

The DDM process was framed as an exercise in appraising 'sustainable energy futures for the UK' to move beyond the narrower frames of previous engagements and consider the whole energy system. We sought to develop a diverse set of visions of the energy system in 2050 for participants to appraise through a review of diverse existing visions and scenarios of future energy transitions for the UK. This included reviewing those set out by: (1) the UK Government, including within the Carbon Plan; (2) business, including the National Grid; (3) civil society, including Greenpeace; and (4) academia, including the UK Energy Research Centre. We identified five key axes of difference between the visions reviewed: different technical assumptions about how energy would be (1) produced, (2) distributed and (3) used, and different social assumptions about (4) growth and (5) governance. With respect to the technical assumptions, some visions emphasised energy produced by fossil fuels and nuclear power, for instance, while others emphasised renewable energy or more speculative technologies. Some visions assumed a centralised power distribution grid run by large energy companies, while others assumed a decentralised grid. Some visions envisaged lowered energy demand through changes to behaviour, while others envisaged improving responsiveness to demand, using more energy efficient technologies, or more radical reductions in usage. With respect to the social assumptions, some visions assumed a model of economic growth that followed the status quo, whereas others assumed alternative models of growth that emphasised non-monetary values. Some visions assumed an energy market regulated by government with little involvement from citizens, whereas others assumed increased government investment, fewer regulations, more localised decision making or citizen-led decision making. The five key axes of difference identified in our review were then used to develop six distinctive and contrasting core visions for appraisal in the DDM process (see Table 1).

These visions were then put into a narrative form, together with illustrative graphics and questions to prompt discussion (see Appendix). Crucially, these visions depart from those in typical processes of public engagement with whole energy systems by describing social dimensions (how they would be governed, how growth would be defined, how equity would be accounted for, who the key actors are) just as much as technical ones (how energy would be demanded, produced and distributed). These sociotechnical visions were illustrated by pointing to proponents or key actors and real-world examples associated with each vision.

During the DDM process participants were also free to add their own, additional visions to appraise (see Table 2). The activist citizens group added an 'environmental justice' vision, which included radical

Table 1
Axes of difference between visions of sustainable energy futures.

	Business as usual	Large tech society	Deliberative energy society	Smart tech society	Local energy partnerships	Radical off-grid living
Summary	A vision of a future where the energy system is similar to how it is now	A vision of a future where new technologies are developed and deployed to reduce carbon dioxide emissions	A vision of a future where the public has much more of a say over what happens with the energy system	A vision of a future where 'smart' technologies are used to make the energy system more connected and efficient	A vision of a future where people work together in partnership for localised energy systems	A vision of a future where communities live 'off-grid'
Core tenets	Continuation of fossil economy by large energy companies	Government and business investment in new technology	Public participation shifts emphasis to renewables	Free market innovation drives lower energy demand	Local energy run by local government and businesses	Radical communities live off-grid
Governance	Market regulated by government for consumers	Government and market investment for consumers	Market regulated by government, includes citizens in decisions	Free market competition with little regulation for consumers	Local government and businesses, includes citizens in decisions	Citizen-led decisions with no government or business involvement
Growth	Status quo	Status quo	Status quo	Status quo	Alternative models of growth that emphasise non-monetary value	Alternative models of growth that emphasise non-monetary value
Key actors	Government, 'Big 6' energy companies	Corporate philanthropists, scientists and technologists	Public dialogue bodies, social scientists	Technology companies, electric vehicle manufacturers	Local energy service companies, energy cooperatives	Radical off-grid communities, transition towns
Production	Fossil fuels and nuclear, fewer renewables	3rd and 4th generation biofuels, carbon removal and nuclear fusion	Renewables supported by fossil fuels	Renewables	Renewables, biofuels and carbon removal	Renewables
Distribution	Centralised grid by large energy companies	Centralised grid by large energy companies	Centralised smart grid by large energy companies	Decentralised smart grid and energy storage	Decentralised smart grid	Decentralised smart grid between energy islands
Demand	Reduction by encouraged behaviour change	Making technologies more efficient	Reduction by encouraged behaviour change and improving responsiveness to demand	Making technologies more efficient and improving responsiveness to demand	Making technologies more efficient	Radical reductions in energy use
Key examples	N/A	Hinkley Point and BECCS in the IPCC RCPs	Public participation activities	Home Energy Management Systems, support for developing electric vehicles	Community wind farms, feed-in tariffs	Isle of Eigg, Lammas eco-village

Table 2
Additional visions of sustainable energy futures defined by DDM groups.

Additional vision	Definition
Environmental justice (defined by activist citizens)	"Collective decision between people and government. Certain things to be managed nationally in the public interest and that includes things like proper regulation of the way things are produced and used, as energy efficiently as possible and we're also saying that some public ownership of infrastructure, things like, I'm guessing offshore wind, for example, where these big projects that it's hard for people to own locally but that could in theory be part of public ownership and then the income from them goes back into the public purse. National structure to be opening up the doors to a kind of blossoming of multiple other kind of solutions all over the country, where people are saying, "We're going to have our own community wind turbine, our own community hydro-power" or we're saying "over here we're going to have a neighbourhood that are going to bulk buy all of their own solar panels and do the entire street including subsidising it for people who can't afford it" and the doors are opened by government to all these different possibilities and opportunities. Certain things like bits of national structure, certain important regulation, investment in research, management of a National Grid that works and prioritises the most important things, but we're also kind of, in some areas the government is stepping forward, in other areas the government is stepping back and saying we want a more decentralised sphere out of which lots of different solutions can emerge, as long as everyone's kind of in this agreed social goal of we want to have this sort of fair access to clean energy for everybody. We're providing everyone with clean fair energy, in order for us to live, like fulfilling positive lives that aren't based on consumerism."
Incremental approach (defined by innovator citizens)	"The obvious one is just bits of all of the other visions, smashed together to make a composite vision, where you do all the easy bits of everything and not do the really hard bits of any of them. So you have some… technologies and you have people more engaged and more educated about their energy usage, using some amount of smart technology, perhaps with the odd community going off-grid or having local energy partnership and the slow end through everything, bringing everything down, bringing your carbon usage down, it's not quite so dramatic a vision as any of these ones but I would suggest it's probably a more realistic one." "I think as in a lot of things, as technology enables it, everything moves closer to being a distributed model rather than being a centralised model, so previously we were talking about big power stations next to coal mines and the distributed supply grid whereas now, it's more cost effective to have a distributed supply and the technology is what's enabling that and the technology is coming up with alternative energy sources like solar, like wind power, like tide power which is not on here as an example, that Swansea Bay or whatever it is, as alternative sources of supply driven by technology, alternative distributed grid in terms of the ability to generate more locally and consume more locally and reduce transmission losses, which is technology enabled and it's a combination of all of these things down here, so local off-grid possibly but not necessarily, local energy sources which is what the various visions were but it's a combination of technology driven, it's a combination of all of those which is making the status quo less relevant and more distributed." "And change coming incrementally in small steps" "Evolution rather than revolution, yes."
Energy/ demand reduction (defined by innovator citizens)	"It is building housing where there's jobs, we've developed a society where we can travel to work over vast distances… Whereas before, if you had a job in Sidford, it was quite a big deal because you had to walk there so it's got to be said that the era of relatively cheap house heating in Victorian times, when coal was becoming an easily available and relatively affordable fuel, resulted in some of the least energy efficient houses we've ever built in our history because of the fact we didn't need to insulate our homes, either high-tech insulation now or very low-tech insulation in the past where you basically built thick walls because you didn't have any way of heating your house other than going out and chopping wood. So to some extent every time you improve the supply, you actually also drive the demand because people, you can become more inefficient so I think trying to drive efficiency would be quite a useful thing but it takes a big societal change… This is the thing, if we had governments who would actually price energy at its real cost rather than at its purely supply cost, it would drive and change behaviour."
Regulation for renewables (defined by consumer citizens)	"A strong government to transition the UK to renewable sources of energy production and legislation to force new buildings to generate renewable energy and be energy efficient."
Maximum demand reduction (defined by specialist S7)	"Major focus on reducing demand for energy in all its forms: electricity, process energy use, heating, transport, embodied energy in goods and services. For example, this would include a huge refurbishment programme across all buildings, supported by minimum efficiency standards, training programmes for installers and builders, supportive incentive and information programmes etc. Energy efficiency would be treated as an infrastructure priority, For the transport sector, this would include technical, economic and social measures which favoured active modes of travel – walking and cycling – followed by low C methods – e.g. electric bikes, public transport etc. By focusing resources and policy on revolutionising the level of demand for energy, less radical change might be necessary on the supply side."

reductions in energy use to a 'fair' level around the world. The innovator citizens group added 'energy and demand reduction' vision, which included pricing the 'true' cost of energy by accounting for externalities, and an 'incremental approach' vision, that included applying the 'easy bits' of the six core visions, incrementally over time. The consumer citizens group added a 'regulation for renewables' vision, which included a strong government-led transition to renewable sources of energy. One specialist added 'maximum demand reduction' vision, which included investment, regulatory and social focus on reducing demand for energy.

2.2. Enrolling participants

The DDM process was composed of five parallel strands of engagement: one for each of our four groups of energy publics – deliberative citizens, activist citizens, innovator citizens and consumer citizens – and one for a fifth, specialists' group (see Fig. 1). Each strand consisted of two phases: (1) participant and group recruitment, and (2) a workshop

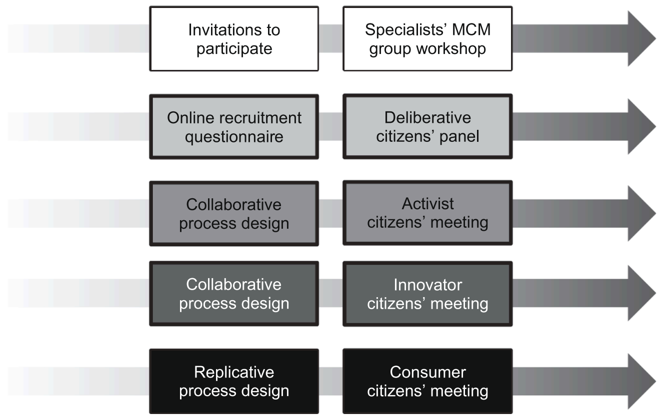

Fig. 1. An overview of the distributed deliberative mapping appraisal method.

in which they appraised different energy futures. The recruitment of the deliberative citizens and specialists' groups followed the established deliberative mapping method, selecting sociodemographically representative citizens through an online survey administered by the research team (see Table 3 for participant codes), and identifying and inviting diverse specialists from across government, industry, civil society and academia (see Table 4 for participant codes). The recruitment of the activist, innovator and consumer citizens groups involved identifying and inviting extant groups of these kinds, respectively: 6 members of an environmental activist group in opposition to a multinational oil and gas company; 11 members of a grassroots Mutual Society seeking to innovate and improve energy efficiency and reduce the carbon footprint of its community; and 8 participants in an energy control equipment trial (see Table 3 for participant codes), of which 6 participants formed part of 3 households participating in the trial [C1 and C4, C2 and C5, C6 and C7]). All citizen participants and groups received an honorarium for their full participation.

2.3. DDM workshops

All workshops followed the same basic DM steps described above of issue framing, defining options, characterising criteria, scoring options and weighting criteria. There were, however, important differences in how these elements were operationalised. To preserve the authenticity of the normal deliberative mapping process, the deliberative citizens and specialist groups followed the same basic procedure as would normally have been done. In particular, the deliberative citizens' panel, convened in Norwich, followed the same, fully facilitated procedure as previous deliberative mapping studies, albeit in a shorter timeframe of one day. This involved group discussions on issues facing the energy system and the visions under consideration, a process of negotiated amalgamation through which individual criteria were consolidated into group criteria, and individual scoring of the visions and weighting of the criteria (see [43] for further details). The specialists' workshop, convened in London, also took place during one day and followed the same procedure as the deliberative citizens group up until characterising criteria. At this point the specialist participants followed the same process as previous deliberative mapping studies, and in particular the specialist-focussed multi-criteria mapping protocol, where they were provided with laptops pre-loaded with multicriteria mapping software to allow them to develop and weight the criteria and score the visions entirely as individuals.

Table 3
Deliberative, activist, innovator and consumer citizen participants.

Deliberative citizens	Activist citizens	Innovator citizens	Consumer citizens
D1 (F)	A1 (F)	I1 (F)	C1 (M)
D2 (M)	A2 (M)	I2 (M)	C2 (M)
D3 (F)	A3 (M)	I3 (M)	C3 (F)
D4 (F)	A4 (M)	I4 (M)	C4 (F)
D5 (F)	A5 (M)	I5 (F)	C5 (M)
D6 (M)	A6 (M)	I6 (F)	C6 (F)
D7 (M)		I7 (M)	C7 (M)
D8 (M)		I8 (M)	C8 (M)
D9 (F)		I9 (M)	
		I10 (M)	
		I11 (M)	

Table 4
Specialist participants.

Code	Gender	Sector	Position
S1	M	Government	Principal civil servant at a UK Government department
S2	M	Government	Chief economist at an independent UK statutory body
S3	M	Civil society	Chief scientist at an international environmental NGO
S4	F	Civil society	Sustainability advisor at a UK sustainability non-profit
S5	M	Industry	Director of policy at one of the 'Big 6' UK energy companies
S6	M	Industry	Manager at an international electricity and gas company
S7	F	Academic	Environmental social scientist from a top UK university

The activist, innovator and consumer citizens' meetings followed quite different procedures to reflect their different models of participation in the energy system. The procedural philosophy here was in each case to preserve the existing atmospheres of democracy. During the recruitment phase, the research team had a point of contact for each group and began a process of collaborative design, whereby the contact would structure the basic method around the typical ways in which their groups would work during their meetings. For the activist citizens group this was a 3.5-hour meeting in London in which the contact (A5) acted as a facilitator. For the innovator citizens group this was a 4-hour meeting in Oxfordshire in which the contact (I7) acted as a facilitator. For the consumer citizens group this was a 4-hour meeting in Wiltshire in which the research team stood in for the energy control equipment trial conveners who would typically facilitate their meetings, to replicate their typical ways of working. The three groups began by following the same basic procedures as the others, with group discussions on issues facing the energy system and the visions under consideration, and individual scoring of the visions and weighting of the criteria; but important differences arose that reflected their different models of participation in the energy system. The activist citizens group devoted much more time to defining their seventh vision, environmental justice. By design, the consumer citizens group devoted time to discussing their experiences of participating in the energy control equipment trial. Later differences arose, too, with the activists developing their criteria through collective deliberation, rather than negotiated amalgamation like the other groups.

The DDM process produced a large body of quantitative and qualitative data for analysis which were analysed using the procedures described in Burgess et al. [43].

There are of course many other models of participation or pre-existing collectives of participation which could also have been included in this DDM process, including those identified in the mapping preceding it, such as forms of online activism and engagement or those participating in artistic projects (see [30]). Our aim in innovating the DM method is not to make a new claim to comprehensiveness in representing public responses to futures, but rather to more deliberately experiment with contrasting atmospheres of democracy to explore how these contribute to shaping public responses. To enable comparison, it was necessary to keep the basic DM process structure the same between the 5 groups and to include the same scenarios. However, our qualitative data also enables us to reflect the different contexts and practices which were observed in each group, which drew from the pre-existing collectives enrolled and their interactions with the DDM process.

3. Results

In this section we begin by reporting the different ways in which the five DDM groups framed the problem to be addressed. We then describe the criteria developed by each DDM group to appraise the sociotechnical visions and how the visions were scored against those criteria. Finally, we examine the overall vision rankings across the DDM groups.

3.1. Problem framings

The five DDM groups engaged with the initial discussion of problems facing the UK energy system in very different ways.

In the **deliberative citizens** group, the participants developed five key frames around what they saw as *a problem of apathy*. The first of these centred on the relative advantages and disadvantages of centralised versus decentralised systems of energy supply. For D5, a centralised system was at odds with local sustainability and represented one which was far more vulnerable to security risks, such as terrorist acts. On the other hand, D7 emphasised the economies of scale that come with larger scale and centralised modes of energy generation. The second frame concerned trust in those governing the energy system. D8 asserted that the public was not always told the truth about new energy technologies, and in particular the costs of wind energy and environmental concerns around nuclear fission energy. The third frame surrounded a lack of public interest in the need for a sustainable energy system. D1 described a particularly negative "general perception of sustainable energy in the UK", referring to ostensibly aesthetically displeasing energy projects like wind farms and biomass burners. Education was seen as a key element in overcoming this indifference, but D8 suggested that there would always be a background level of reluctance to change. The fourth frame concerned energy affordability, in which D4 considered this as both a fuel poverty problem and one of restricted access to domestic renewable energy schemes or fuel-efficient technologies. The fifth frame centred on repair; with D3 recalling how older generations saved more energy through repairing and reusing consumables rather than buying new ones.

In the **activist citizens** group, the participants developed four key frames around what they saw as *a problem of fairness*. The first of these frames focussed on issues of equity within and between countries. For A4 and A5 this concerned not only issues of access to energy and energy affordability for the most vulnerable in society, but also inequitable environmental impacts throughout energy supply chains, particularly those associated with fossil fuel extraction. The second frame concerned cultural environmentalism and how some countries, notably Germany, could be seen to be 'greener' than others in their efforts to develop more sustainable energy systems. The third frame surrounded a perceived governmental undermining of sustainability agendas. A1 and particularly A3 saw the government as actively seeking to "cripple" sustainability in the UK. They pointed to a lack of subsidies received by renewables when compared to fossils fuels at the same stage of development. A3 angrily criticised them and the media for, in his view, undermining renewables and not entertaining the notion of 'turning the lights off'. The fourth frame concerned the propriety of markets for delivering a sustainable energy system. A6 suggested that with a 'level playing field' the energy market could be fairer, while A1, A2 and A3 emphasised the fact that the full extent of externalities were never accounted for in free markets.

In the **innovator citizens** group, the participants developed five key frames around what they saw as *a problem of management*. The first of these centred on climate change risk and uncertainty. I4 was sceptical of the human causes of climate change, but recognised that tackling the problem was "important irrespective" because of the environmental impacts of fossil fuel extraction. I11 responded with concern about how, if there was even uncertainty within a group that was actively pursuing sustainability, the rest of society could be convinced of taking action. He instead framed the problem in terms of 'risk management', hedging in the face of uncertainty. The second frame concerned government timescales and how short electoral cycles meant that short-term political goals, such as pleasing voters with cheaper energy tariffs, were prioritised over long-term sustainability goals. The third frame concerned the scale of the sustainability problem. Responding to the scepticism of climate change raised by I4, I5 situated the sustainability problem in the broader context of human impacts on the world over the Earth's history. The extent and rapidity of those changes, she argued, called for global and local efforts towards sustainability. For I6, the scale of the problem induced a more fatalistic response. The fourth frame, to which the participants dedicated more of their discussion time, concerned using smart-technologies to manage demand and storage. However, they were considered only useful at the micro level of households and not at the macro level of whole societies. I7 implied that a less centralised distribution system could help to overcome this problem, but I6 pointed out that the centralised system brought with it greater economies of scale. The fifth frame concerned a perceived deficit of understanding among younger people in particular and the need to more effectively engage them with sustainable energy systems.

In the **consumer citizens** group, the participants developed four key frames around what they saw as *a problem of regulation*. The first of these focussed on a desired role of government in helping the UK and its citizens become more sustainable in their use of energy, noting that it was currently not fulfilling this role through an ongoing commitment to unsustainable fossil fuels. The second frame concerned the apparent under-exploitation of alternative energy sources. This related to both national and local sources of energy production, and was blamed in particular on 'experts' for contributing to a sense of uncertainty and leading to inaction among decision makers. The third issue surrounded a perceived need for all new buildings to be made sustainable, with the participants once again emphasising the desired role of government in making that possible through legislation. The fourth frame was about the need for energy security and a national self-reliance.

In the **specialists** group, the participants developed three key frames around what they saw as *a problem of inertia*. The first of these focussed on system inertia. For S5 this meant inertia in the energy market, which was not designed for transitioning to a low carbon economy. S3 took a much broader view, including inertia in politics and assets as well as in the mind-sets and behaviour of citizens. The participants suggested quite different explanations for these inertias, including perceived high costs of a transition (S6), uncertainty about which energy futures would be best (S1) and the complexity of divergent stakeholder perspectives (S4). The second frame, advanced by S7, surrounded how concerns about cost and security of supply were getting in the way of wider visions for a low carbon society. The third frame, advanced by S4, concerned a lack of government support for first movers in society that did not suffer from inertia and were already getting on with the transition to a low carbon society.

3.2. Criteria development

The five groups developed a diversity of distinctive criteria with which to appraise the different visions of a sustainable energy system for the UK (see Table 5).

In the **deliberative citizens** group, the participants developed a balance of technical and social criteria that were consolidated into six clusters. The most highly weighted of these was environmental damage, where the participants were concerned about the general environmental impacts a vision might have as well as those more specifically on flora, fauna and the landscape, the consumption of resources, the sustainability of food supplies and waste production. Cost effectiveness was moderately weighted, comprising concerns about the general 'cost' and 'affordability' of implementing a vision, costs to consumers, and the

Table 5
Classification of weighted criteria across the five DDM groups.

Criteria	Deliberative citizens	Activist citizens	Innovator citizens	Consumer citizens	Specialists
Technical feasibility	Feasibility ($\bar{x}$ = 16.7%)	Practical timeliness ($\bar{x}$ = 14.3%)	Technical achievability ($\bar{x}$ = 24.6%); Speed of delivery ($\bar{x}$ = 22.7%)	Feasibility ($\bar{x}$ = 20.6%)	Technical feasibility ($\bar{x}$ = 18.5%)
Carbon reduction	–	Avoiding runaway climate change ($\bar{x}$ = 14.3%)	Carbon saving effectiveness ($\bar{x}$ = 24.6%)	–	Carbon reduction ($\bar{x}$ = 33.2%)
Environmental impacts	Environmental damage ($\bar{x}$ = 32.2%)	–	Risk reduction ($\bar{x}$ = 15.5%)	Environmental quality ($\bar{x}$ = 21.3%)	Environmental consequences ($\bar{x}$ = 27.3%)
Economic efficacy	Cost effectiveness ($\bar{x}$ = 18.9%)	–	Cost effectiveness ($\bar{x}$ = 7.3%)	Cost effectiveness ($\bar{x}$ = 21.3%)	Economic feasibility ($\bar{x}$ = 18.9%)
Political practicality	Efficacy of governance ($\bar{x}$ = 10.0%)	–	–	Energy security ($\bar{x}$ = 21.3%)	Societal plausibility ($\bar{x}$ = 15.8%); Vision flexibility ($\bar{x}$ = 13.9%)
Public acceptability	Social acceptability ($\bar{x}$ = 7.9%)	Meaningfulness of influence ($\bar{x}$ = 14.3%); Progress to an active public ($\bar{x}$ = 14.3%)	Public acceptability ($\bar{x}$ = 5.5%)	Participation increase ($\bar{x}$ = 15.6%)	Public acceptability ($\bar{x}$ = 17.8%)
Societal fairness	Fairness ($\bar{x}$ = 14.4%)	Progress to global justice ($\bar{x}$ = 14.3%); Fair quality of life ($\bar{x}$ = 14.3%); Redistribution of power ($\bar{x}$ = 14.3%)	–	–	Equity of benefits ($\bar{x}$ = 27.4%)

Note: In cases where a criterion overlapped with another criteria cluster, the aspect emphasised during the appraisals was used to categorise the criterion. Mean group weights for each criteria cluster are given in parentheses.

eventual costs of any decommissioning. Technical feasibility was weighted slightly lower, focussing on a visions' infrastructure requirements, flexibility to changes in demand and longevity. Fairness was weighted slightly lower, and consisted of concerns about the fairness of energy prices, who would benefit from the visions and who would bear any risks, who would be in control and what the impacts might be on our relationships with other countries. The efficacy of governance was weighted lower still, focussing on how a vision would be 'implemented', 'managed' and 'controlled', how profit taking would be regulated and who would be held responsible. Social acceptability was the lowest weighted criterion, consisting of concerns about general societal 'implications' and 'acceptance' as well as more specific concerns about trust in those steering the transition, possible conflicts of interest, a need for wider public engagement and the capacity to educate people about energy.

In the **activist citizens** group, the participants developed a set of seven, primarily social, criteria which they opted to weight equally. The first of these focussed on the extent to which a vision was likely to lead to the avoidance of runaway climate change. The second criterion concerned the extent to which a vision would improve the quality of people's lives in a fair and equitable way. Access to nature, affordable energy, clean air and healthy food were core tenets of this criterion. The third criterion centred on the practical timeliness of visions and the plausibility that one could be proven and implemented within desired timeframes. The fourth criterion focussed on a redistribution of power, where a shift in power and wealth away from a central few and corporate interests was considered desirable. The fifth criterion probed the extent to which a vision would give people a 'meaningful' say over how energy is produced, distributed and used. This notion was developed further in the sixth criterion in which visions would be appraised against their capacity for moving society towards what the activist citizens described as having 'an engaged, aware and active public on issues of social justice, equity and global environmental justice'. The seventh and final criterion focussed on the extent to which visions would move the world towards 'global justice' in which everyone would have access to 'affordable energy, fairness and justice, clean air, access to nature and fresh healthy food'.

In the **innovator citizens** group, the participants developed a set of six, primarily technical, clusters of criteria. One of the two joint-most highly weighted of these was carbon saving effectiveness, where the participants were concerned with the extent to which visions would be likely to reduce carbon emissions, reduce aggregate demand for energy, reduce energy losses during transmission or reduce waste. The other joint-most highly weighted criterion was technical achievability, which consisted of general issues of 'feasibility' or 'achievability' as well as more specific issues surrounding the level of knowledge that might be required to implement a vision, its likelihood of delivering its desired effects, and how easily maintained and sustained it would be. Speed of delivery was moderately weighted, and was solely concerned with how long it would take before the implementation of a vision would be completed. Risk reduction was weighted slightly lower, focussing on the extent to which a vision would reduce the risks posed by climate change, how significant the risks would be if the vision failed, and whether it would be open to manipulation by third parties. Cost effectiveness was weighted lower still, looking at issues of high level 'cost', 'cost effectiveness', 'economic feasibility' as well as more personal levels of 'affordability'. Public acceptability was the lowest weighted criterion, consisting of concerns about general 'acceptability' as well as how much individual 'action' or 'inconvenience' a vision might necessitate.

In the **consumer citizens** group, the participants developed a set of five, primarily technical, clusters of criteria. One of the three joint-most highly weighted of these was environmental quality, where the participants were concerned with the extent to which visions would be likely to protect the environment, bring about carbon neutrality and mitigate climate change, remove our reliance on fossil fuels or nuclear energy and prevent soil degradation in the service of sustainable food production. The second most highly weighted criterion was cost effectiveness, which comprised general concerns about 'economic benefit', 'cost' or 'cost of energy' as well as more particular 'costs to consumers'. The third most highly weighted criterion was energy security, which focussed on the capacity of a vision to deliver a 'secure' or 'sustained' supply of energy. Feasibility was weighted slighted lower, and consisted of concerns about general 'feasibility' or 'practicality' as well as more specific concerns about continued feasibility after 2050, the speed with which a vision could be implemented and its 'workability' in different geographical locations. The extent to which a vision would bring about an increase in public participation was the lowest weighted criterion, focussing on general levels of 'involvement' and 'empowerment' as well as community ownership of energy resources, degrees of private control and choice over energy, and social and educational co-benefits.

In the **specialists** group, the participants developed a balance of technical and social criteria that can grouped into eight clusters. The most highly weighted of these were criteria that centred on carbon reduction. In particular, the participants were concerned with the extent to which visions could decarbonise the energy system, help reach government carbon reduction 'targets' or 'budgets', bring behavioural changes that would reduce carbon footprints, or just generally 'reduce' or 'abate' carbon emissions. Equity of benefits criteria were also highly weighted, focussing on the extent to which visions would bring 'fair', 'equitable' or 'equal' impacts on society, that the pace of change would be tempered by a 'just' system, or that visions would simply bring 'benefits' or 'net positive' changes to society. Economic feasibility criteria were moderately weighted, focussing on the general 'cost' and 'affordability' of different visions, as well as their compatibility with existing markets, capacity to match supply and demand at the lowest cost, and contribution to sustainable business growth. Technical feasibility criteria were weighted similarly, focussing on general 'feasibility' or 'plausibility' at scale, as well as the readiness of infrastructure for any changes required by the vision, the dependence of the vision on research and development, and the availability of technologies relied upon in the vision. Public acceptability criteria were weighted slightly lower, and centred on the perceived general 'plausibility' of public 'acceptance', the scope for multi-stakeholder engagement within a vision, and customer access to their data. Societal plausibility was weighted lower still, and focussed on the perceived 'believability', 'realism', 'ease of transition' or levels of 'political change' or 'social reorganisation' needed to implement a vision. Vision flexibility was the lowest weighted group of criteria, exploring the 'flexibility' or 'resilience' of a vision to possible future circumstances and its compatibility with other visions. Although weighted highly, environmental consequences were only taken forward as a criterion by one participant (S3).

3.3. Vision scoring

3.3.1. Technical feasibility

Technical feasibility criteria were developed and applied by all five of the groups.

Large-scale technologies, deliberative energy society and off-grid energy communities were the lower performing visions against technical feasibility criteria. While some of the **large-scale technologies**, such as biofuels were considered well developed and a good fit with existing infrastructures, large uncertainties were expressed over whether particular technologies could be implemented at scale, or indeed at all, notably nuclear fusion and CCS. The vision was among the lowest performing for the specialists, activist and consumer citizens groups. The technologies of the **deliberative energy society**, on the other hand, were deemed to be already proven and in place, but widespread participation was thought to risk a chaotic situation where there was no overall control over the energy system. This vision was among the lowest performing for the innovator and consumer citizens groups. Concerns about the feasibility of **off-grid energy communities**, which were among the lowest performing visions for the innovator and consumer citizens groups, were less about its technologies than they were about its niche appeal.

> "I think there are some big issues around large-scale technologies, particularly CCS and nuclear in terms of proven-ness and need for demonstration." (S5 on LST)
> "There won't be any real control over it." (C5 on DES)
> "A bit of a niche thing that is going to happen in a few places but probably not very relevant for others." (I7 on OGC)

Local energy partnerships, smart-tech society and business as usual were the higher performing visions against technical feasibility criteria. **Local energy partnerships**, which were among the highest performing visions for the deliberative and activist citizens groups, and **smart-tech society**, which was among the highest performing visions for the innovator and consumer citizens groups, were deemed to be already happening at different scales or where society was headed anyway, respectively. For smart-tech society, however, challenges were foreseen if the onus for smart energy usage was placed on the consumer. While **business as usual**, which was among the highest performing visions for the specialists, activist and innovator citizens groups, was considered feasible in that it was already happening, participants felt that it would not continue because of the depletion of finite fossil fuels and growing pressures for sustainability.

> "The school solar panel campaign is already being rolled out, home solar panel getting reduced tariff, it's already happening in varying scales." (D5 on LEP)
> "The other big challenge with this one is if we assume that there is both supply and demand based smart-technology, you could have massive infrastructure by the government nationally but if people have to buy smart dishwashers themselves, that's a capital cost that a household has to make." (I1 on STS)
> "At some point, business as usual will start to become technically unfeasible as resources deplete, like far into the future so there is a risk." (S1 on BAU)

For the specialist who developed their own additional, **maximum demand reduction** vision (S7), this option was criticised for its technologies not being installed at a large scale.

3.3.2. Carbon reduction

Carbon reduction criteria were developed and applied by the specialists, activist citizens and innovator citizens groups.

Business as usual, deliberative energy society and large-scale technologies were the lower performing visions against carbon reduction criteria. The heavy reliance on fossil fuels of **business as usual**, which was among the lowest performing visions for the specialists, activist and innovator citizens groups, was seen to make the vision simply incompatible with carbon reduction targets. Building on concerns about the feasibility of **deliberative energy society**, which was among the lowest performing visions for the activist and innovator citizens groups, participants were concerned that disagreements would lead to inaction on carbon reduction. Similarly, concerns about the feasibility of some **large-scale technologies**, which was among the lowest performing visions for the activist citizens group, led to uncertainties about their potential to deliver carbon reduction.

> "Best case scenario, utterly impossible, worst case scenario is even worse!" (A3 on BAU)
> "How would you ever get anything passed with all the disagreements?" (I6 on DES)
> "Same with capture and storage, it's not proven. Fusion, I think is mentioned in this one, I'm not sure whether that's going to happen, so the downside for me is more whether in practice things these will come through to the scale that is needed." (S2 on LST)

Local energy partnerships, off-grid energy communities and smart-tech society were the higher performing visions against carbon reduction criteria. All were praised for their heavy shifts towards renewable energy sources, which were seen as eminently more compatible with carbon targets. While reservations over a **smart-tech society** were limited, being among the highest performing visions for the specialists and innovator citizens groups, **local energy partnerships** were criticised for their reliance on BECCS, which was seen as not being available or supportable in many localities. It was, however, among the highest performing visions for the specialists group. Similarly, the limited uptake of **off-grid energy communities**, which was among the highest performing visions for the specialists and activist citizens groups, was nevertheless seen to translate into a critical limiting factor to carbon reduction.

> "I can see that smart-tech and off-grid scored the two highest and that is because they're the only ones which say that energy is almost entirely supplied by source of renewable energy." (S1 on STS)
> "If those partnerships are prioritising renewables and they're prioritising low carbon options, it's completely consistent but I have doubts about how much bio-energy for example would be available at a local level, so whether you could move away from some of the big technologies, whether it's nuclear, capture and storage or

whatever, whether the alternatives are available at the scale that would be needed…" (S2 on LEP)

"I just thought you can't get anywhere, a drop in the ocean." (S5 on OGC)

For the specialist who developed their own additional, **maximum demand reduction** vision (S7), this option was among their highest performing visions for its compatibility with a wholly renewable energy supply.

3.3.3. Environmental impacts

Environmental impacts criteria were developed and applied by the specialists, deliberative citizens, innovator citizens and consumer citizens groups.

Business as usual, large-scale technologies and off-grid energy communities were the lower performing visions against environmental impacts criteria. The reliance of **business as usual** on fossil fuels and their resultant environmental impacts were often considered by participants to go without saying, with the vision being among the lowest performing for the deliberative, consumer and innovator citizens groups. Similarly, **large-scale technologies**, which were among the lowest performing visions for the specialists and innovator citizens groups, were viewed as promoting a so-called 'fetishisation' of carbon. While the focus on renewable energy in **off-grid energy communities** was viewed as laudable, its niche appeal was deemed to offer only minimal environmental improvements. It was among the lowest performing visions for the innovator citizens group.

"I think it's generally accepted that we're going in the wrong direction!" (D2 on BAU)

"Pollution, land use, resource use… and I score [this] very low because of what I would call the fetishisation of carbon." (S3 on LST)

"I think for a community to go off-grid, you've got to get the 100% buy-in of everybody in the community. If 1 in 100 say 'you're not telling me what to do', you're not going to." (I4 on OGC)

Deliberative energy society, smart-tech society and local energy partnerships were the higher performing visions against environmental impacts criteria. While Brexit and the election of Donald Trump were cited as reasons not to trust public inclinations on important and complicated matters, citizens of the **deliberative energy society** were expected to be interested in their environment and, if given more control, would make it work. It was moreover praised for its emphasis on environmentally sound local accountability chains, ranking among the highest performing visions for the specialists and deliberative citizens groups. By contrast, the reliance of **smart-tech society** on depleting resources around the world for the manufacture of ever more smart-technologies was a cause for concern. Conversely, it was seen to offer much greater energy efficiency, and ranked among the highest performing visions for the innovator and consumer citizens groups. Like the deliberative energy society, the local accountability brought by **local energy partnerships**, which were among the highest performing visions for the specialists, deliberative and innovator citizens groups, was seen as a key factor in minimising environmental impacts.

"I tend to think local accountability chains for this stuff really matter, which is why [it] score[s] highly… If your energy and resources are drawn significantly from being local, it militates against certainly local pollution, it militates against really poor land use." (S3 on DES)

"I think that in a good situation, the majority will take it on board and it will be very efficient." (C4 on STS)

"The actual environmental damage is going to be a lot less because you're not consuming as much are you?"… "And it's likely to take advantage of locally available energy sources"… "And those are more likely to be renewable." (D2, D6 and D9 on LEP)

For the consumer citizen group, their own additional, **regulation for renewables** vision was among their highest performing visions for its capacity to force people to be more environmentally conscious.

3.3.4. Economic efficiency

Economic efficacy criteria were developed and applied by the specialists, deliberative citizens, innovator citizens and consumer citizens groups.

Business as usual, off-grid energy communities and deliberative energy society were the lower performing visions against economic efficiency criteria. High energy prices and the reliance of **business as usual** on finite fossil fuels was seen to drive up costs in the longer term and the impacts of climate change caused by those fuels were deemed to pose costs of their own. The vision was among lowest performing for the deliberative, innovator and consumer citizens groups. While service expectations for **off-grid energy communities** were understood to be adaptable to ensure affordability, it was also felt that lower economic growth and poor economies of scale would raise costs and result in regular blackouts, inefficiencies and insecurity. This vision was among the lowest performing for the specialists and innovator citizens groups. **Deliberative energy society** was viewed positively for enabling citizens to participate in defining what costs are acceptable to them. However, it was thought that administrative costs for involving the public would be high, and that people could choose a lower quality of energy provision when faced with a choice between cost and the environment. It ranked among the lowest performing visions for the innovator citizens group.

"Bills have been going up every year for the past 20 years, even though wholesale prices now are lower than they ever have been, electricity bills are not coming down." (C2 on BAU)

"I see this as high cost because I see low economic growth in this world, fundamentally." (S2 on OGC)

"If people have more involvement in energy, they may… accept a lower level of connection or quality when faced with a choice of cost or environmental consequences, so that would reduce your level of secure supply." (S6 on DES)

Large-scale technologies, local energy partnerships and smart-tech society were the higher performing visions against economic efficiency criteria. On the one hand, **large-scale technologies** were seen to need considerable funding in order to be realised, but on the other, once realised they were seen to bring much greater economies of scale. It was among the highest performing visions for the specialists and deliberative citizens groups. **Local energy partnerships** were deemed eminently affordable, with communities determining what they could afford. Indeed, the consumer citizens group commented on their own experience of this, ranking the vision among their highest performing. **Smart-tech society** was praised for encouraging entrepreneurship and, through its smart-technologies, for being an enabler of energy efficiency, but its deregulation was seen to leave the energy system open to control by monopolies. Nevertheless, that many people already had smart phones and meters led participants to believe that it would be low cost to implement. It was among the highest performing visions for the specialists, innovator and consumer citizens groups.

"There is an issue that is the current model actually going to fund it?" (S5 on LST)

"I think it's worked really well, it could go across the whole country." (C1 on LEP)

"It could be a real enabler to make more efficient delivery of energy security and the smartness of the technology, the smartness of the system; it's actually improving it rather than disrupting it." (S6 on STS)

For the specialist who developed their own additional, **maximum demand reduction** vision (S7), this option was criticised for the possibility that retrofitting could be more expensive than expected.

3.3.5. Political practicality

Political practicality criteria were developed and applied by the specialists, deliberative citizens and consumer citizens groups.

Business as usual, off-grid energy communities and large-scale technologies were the lower performing visions against political practicality criteria. Despite the governing apparatus for **business as usual** was considered to already be in place, and with new regulations coming into force to encourage competition between suppliers, the big energy companies were still seen to dominate the market and lock out alternatives. The vision was among the lowest performing visions for the specialists, consumer and deliberative citizens groups. **Off-grid energy communities** suffered from the opposite problem, that is it was seen as demanding too radical a change in societal values and only being compatible with very particular small, rural communities. It was among the lowest performing visions for the specialists group. Like business as usual, the required systems and networks for **large-scale technologies** were seen as largely in place already, but that this would reinforce the same governance concerns. Their unproven status and lack of government support were seen as drawbacks to societal plausibility and energy security. Their reliance on large energy companies and a centralised grid were moreover seen to be inflexible and going against trends towards smaller, more distributed suppliers. The performance of this vision were more ambiguous for each of the groups, ranking neither among the lowest nor the highest performing.

> "If we go down the business as usual route, pessimistically, you're locking yourself into, you're stopping alternatives, you're stopping that happening… It's a bit of a blocker." (S6 on BAU)
>
> "Bonkers, people aren't going to stand for the level of quality or the cost to the energy at that level, you're losing out all the efficiencies and all the sharing that you would have that the existing system gives you, so share and reserve, ripping up gas networks and putting heat networks in is very disruptive, it's very costly so even in an optimistic world, it's a niche product, it doesn't come out very well to UK wide." (S6 on OGC)
>
> "It seemed quite fixed in maybe its plan rather than it being broader, it's also still a large energy company via centralised grid, so to me that is less flexible and adaptable." (S4 on LST)

Smart-tech society, deliberative energy society and local energy partnerships were the higher performing visions against political practicality criteria. The deregulation in **smart-tech society** was considered by participants to be incompatible with effective governance, with companies controlling personal data and the threat of autonomous technologies to employment. On the other hand, it was seen as compatible with other visions, was viewed positively for its utilisation of a flexible, decentralised grid and was ultimately seen as 'where society is headed'. It was among the highest performing visions for the specialists group. Conversely, **deliberative energy society** was criticised for its reliance on a less flexible centralised grid, but it was seen to make decision making on energy more democratic and employ a good mix of energy technologies. It was among the highest performing visions for the specialists group. **Local energy partnerships** shared these same benefits and with a flexible decentralised grid, with the vision ranking among the highest performing visions for the specialists, deliberative and consumer citizens groups.

> "Deregulation, which I think is incompatible with effective governance"… "If you're making the rules yourself, you're more likely to bend them" (D6 and D2 on STS)
>
> "It's still centralised, it is smart but it's still via larger energy companies so to me that hasn't got that same level of flexibility, still regulated by government." (S4 on DES)
>
> "The prosumer element, the potential to have a localised and centralised side of things and especially with the local one because that allows for that localised adaptation and that flexibility, depending on the different contexts." (S4 on LEP)

For the specialist who developed their own additional, **maximum demand reduction** vision (S7), this option was among their highest performing visions because reduced demand was seen to inherently increase system resilience.

3.3.6. Public acceptability

Public acceptability criteria were developed and applied by all five of the groups.

Business as usual, large-scale technologies and off-grid energy communities were the lower performing visions against public acceptability criteria. While the public was considered to support the status quo of **business as usual** the participants perceived there to be a growing unacceptability about its contribution to climate change and the lack of their involvement in decision making, where the 'rules' of the energy system were seen to be written by the big energy companies. The vision was among the lowest performing for all groups, with the exception of the innovator citizens group for which it was among the highest performing. **Large-scale technologies**, which were among the lowest performing visions for the activist and consumer citizens groups, were seen as likely to raise public concerns, but only for those directly affected. Conversely, **off-grid energy communities**, which were the lowest performing visions for the innovator citizens group, were deemed likely to be acceptable, but only to niche publics and places.

> "I sort of feel there's actually a chance with the business as usual that they would be if it gets so bad, that it wakes people up… A rising consciousness." (A6 on BAU)
>
> "It's unlikely to be in my back yard." (I1 on LST)
>
> "I think off-grid communities like the Lammas Peak in Wales, they're the people who have become a community because of the shared vision, rather than the other way round… They sort of gravitated towards each other." (I7 on OGC)

Deliberative energy society, smart-tech society and local energy partnerships were the higher performing visions against public acceptability criteria. **Deliberative energy society**, which was among the highest performing visions for the specialists, deliberative and activist citizens groups, was praised for its strong emphasis on public involvement in decision making. Similarly, **smart-tech society** was praised for providing data for active energy management but public concerns over data security were also noted. The fact that people already had many of the technologies necessary for the vision allowed participants to see the next steps towards public acceptance as incremental. It was among the highest performing visions for all groups, with the exception of the activist citizens group. Again, **local energy partnerships** were seen positively for their public involvement in decision making, but they were not considered to have a widespread appeal. This vision was among the highest performing for all of the groups.

> "Obviously here it's saying you've got members of the public that are active participants" (S4 on DES)
>
> "We've got the phones, we've got the computers, and this is just the next step isn't it? We're already there"… "I think society is blinded towards technology, they've all got smartphones." (D5 and D2 on STS)
>
> "It's the partnerships that really emphasises the multi-stakeholder [aspect]." (S4 on LEP)

For the consumer citizen group, their own additional, **regulation for renewables** vision was among their highest performing visions because forcibly taking on renewables was seen to similarly force direct participation with energy.

> "They've got a little turbine on their house or in their garden or solar panels, they're going to get more involved." (C4)

3.3.7. *Societal fairness*

Societal fairness criteria were developed and applied by the specialists, deliberative citizens and activist citizens groups.

Business as usual, large-scale technologies and smart-tech society were the lower performing visions against societal fairness criteria. **Business as usual** was condemned for its perpetuation of fuel poverty and fossil fuel driven detrimental impacts on the climate and wider environment. Participants were also concerned about the perpetuation of market monopolies or effective cartels. It was among the lowest performing visions for all of the groups. Similarly, participants were concerned about the potential for energy or technology companies to form market monopolies in the case of **large-scale technologies**. On the other hand, the greater carbon reduction potential and better economies of scale associated with this vision were seen to promise greater societal fairness. The vision was among the lowest performing for the deliberative and activist citizens groups. The perceptibly narrow focus of **smart-tech society** on economic growth was seen to promote a similarly narrow sense of justice. It was among the lowest performing visions for the activist citizens group.

> "They're in a monopoly, worst case scenario, they're in the monopoly position, and they could form an effective cartel of sorts and rig the market." (D5)
> "I think yes, I think it's because my belief is that the technology's large scale and economics of scale, I'm slightly doubtful about the, shall we say, medium scale, the local initiatives on generation." (D7)
> "I'm quite pessimistic here… meters are still like, looking at money, it doesn't mean that's a sense of justice for everyone." (A1)

Deliberative energy society, off-grid energy communities and local energy partnerships were the higher performing visions against societal fairness criteria. Reflecting citizens' wants and needs in decision making were judged positively under **deliberative energy society**, which ranked among the highest performing visions for the specialists group, but it was also seen to not bring 'net-positive' benefits over and above carbon reduction. While society was seen to benefit from alternative measure of growth under the **off-grid energy communities** vision, it was criticised for not engaging everyone, fostering factionalism and creating wealth inequities between different communities. A notable disagreement between two participants in the activists group neatly illustrated this, despite the vision ranking among the highest performing visions for the group. Reflecting citizens' wants and needs in decision making and making use of cheaper, local energy sources led to **local energy partnerships** being viewed positively, with the vision among the highest performing for all of the groups.

> "The public has much more of a say of what happens to them so there is that potential but again, you're reliant on that, it says it's regulated by government, you're relying on that being effective and also it's not even a smart grid, it's just a grid." (S4 on DES)
> "If people don't want to be off-grid and it's a negative development for them, then maybe it's not massively empowering"… "But that's wrong because we're not talking about the journey, we're talking about the end result." (A1 and A2 on OGC)
> "I think this is the one for me of all of these options that is the most likely to result in a fair outcome because by definition, it's a community initiative, it's consensual, you get out of it what you put into it." (D6 on LEP)

3.4. *Vision rankings*

Fig. 2 shows the final performance rankings for each of the six core sociotechnical visions plus the five additional visions under the perspectives of each of the five DDM groups. As can be seen, the groups produced distinctive vision rankings and patterns of internal ambiguity. Excluding the participant- and group-defined additional visions, which more often than not were the highest performing vision for each group, respectively, the mean rank order across the five groups reveals three tiers of overall core vision performance. The **two highest ranking visions** were:

- A smart-tech society (ranked highest by innovator citizens, consumer citizens and specialists, but second lowest by deliberative citizens)
- Local energy partnerships (ranked highest by deliberative citizens and second highest by activist citizens and consumer citizens)

The **two middle ranking visions** were:

- Off-grid energy communities (ranked highest by activist citizens and second highest by deliberative citizens but second lowest by innovator citizens and specialists)
- Deliberative energy Society (ranked second highest by specialists but lowest by innovator citizens)

The **two lowest ranking visions** were:

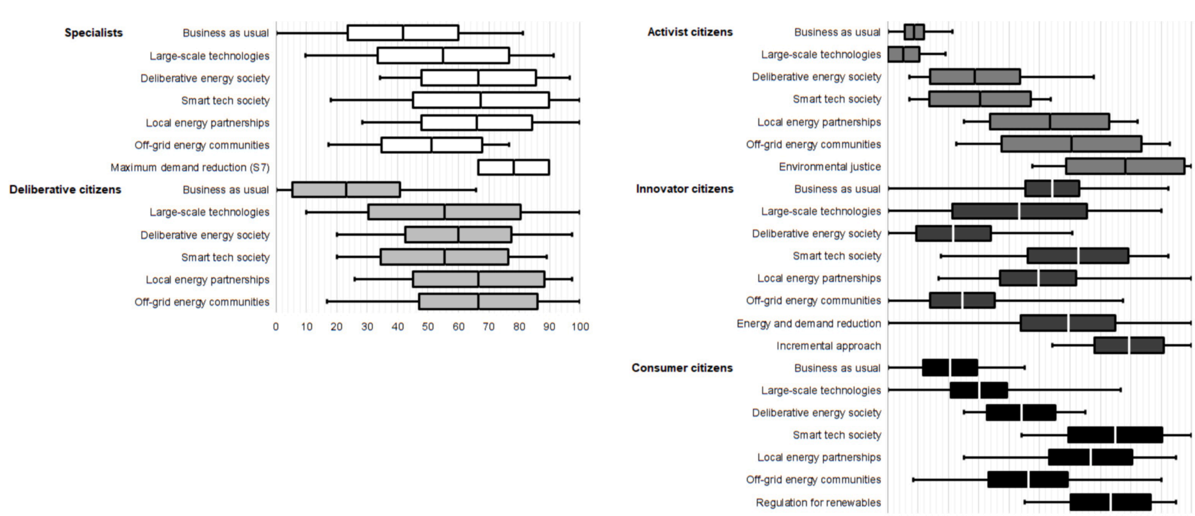

Fig. 2. Final rankings of core and additional visions appraised by specialists, deliberative citizens, activist citizens, innovator citizens and consumer citizens. The length of the thick bars represents the mean difference in performance under optimistic and pessimistic assumptions. The length of the error bars represents the extremes in performance under optimistic and pessimistic assumptions.

- Large-scale technologies (ranked lowest by activist citizens and second lowest by consumer citizens)
- Business as usual (ranked lowest by deliberative citizens, consumer citizens and specialists and second lowest by activist citizens, but second highest by innovator citizens)

4. Discussion and conclusions

Public appraisals of energy futures have to date downplayed the fluid and diverse ways in which citizens participate in the energy system by adopting relatively fixed and narrow framings. In this paper we have reported on a study that pioneered a more distributed approach, intentionally experimenting with diverse normativities of participation by broadening out and opening up to diverse models of participation and associated energy publics. In this regard, we have made two key contributions to the literature.

The first key contribution is that our approach has made different models of participation a key comparative experimental focus in the energy field for the first time. In doing so, a greater diversity of problem framings through which sustainable energy futures are conceived were elicited, going beyond narrow foci on aspects of the energy trilemma. Rather than a problem of climate change, energy security or affordability then, these included energy futures as multifaceted problems of apathy (deliberative citizens), fairness (activist citizens), management (innovator citizens), regulation (consumer citizens) and inertia (specialists). A greater diversity of technical and social criteria with which to appraise the visions followed. These seven criteria clusters are consistent with and operationalise – yet also expand on – existing public values that have been elicited pertaining to energy system change (see [7,20]). These include technical feasibility; carbon reduction (cf. reduced energy use and use of finite resources); environmental impacts (cf. environment and nature, efficient and not wasteful use of energy); economic efficacy; political practicality (cf. a secure and stable energy system); public acceptability (cf. improvements in quality of life); and societal fairness (cf. autonomy and power, justice and fairness). Importantly, however, the criteria developed in our DDM process recognise that public values are not unitary but diverse, often conflicting, and mobilised in different ways. For instance, public acceptability is itself viewed and weighted differently, being reduced to passive ‘acceptance’ in the case of innovator citizens and amplified to active citizen empowerment in the case of activist citizens.

The second key contribution is that our approach has paid greater attention to the social futures and dimensions of energy system change in how the appraisal process is framed [3,5]. In doing so, a greater diversity of visions have been developed (and additional, participant-defined visions invited) to provide participants with a more plural range of futures to consider, emphasising their sociotechnical constitution over and above purely technical features of the energy system. A different view of vision performance followed, where incumbent visions of centralised energy system, such as business as usual and large-scale technologies, perform much lower than decentralised alternatives, such as a smart-tech society and local energy partnerships. This is in contrast with existing public appraisals of energy system transformation, where centralised and policy-oriented imaginaries of energy system change often dominate (e.g. [7]).

A number of common features can be identified among the lower and higher performing visions, respectively. The lower performing visions involve central government regulation and investment in the energy market for citizens as consumers, whereas the higher performing visions involve deregulated free market competition or local government control where citizens are included in decision making. The lower performing visions involve a model of growth that upholds the status quo, whereas one of the higher performing visions involves an alternative model of growth where non-monetary values are emphasised. The lower performing visions involve energy supply by fossil fuels and nuclear fission or fusion, whereas the higher performing visions involve renewables. Novel technologies like biofuels combined with carbon capture and storage feature in both lower and higher performing visions, with them forming smaller scale, local supplies in the latter. Energy distribution is centralised and led by large energy companies in the lower performing visions, while being decentralised in combination with a smart grid in the higher performing visions.

Crucially, the rankings and patterns of the activist, innovator and consumer citizens groups’ appraisals diverge from the deliberative citizens’ rankings and patterns, providing empirical confirmation that methods of public participation need to broaden out and open up beyond sociodemographically representative publics if they are to account for the more systemic and plural realities of public appraisals. Our approach has furthermore underscored the need for combining deliberative mapping with mapping ecologies of participation, and vice versa [26]. The identification of four diverse energy public groups and their associated models of participation emerged from the broader mapping of public participation with energy, and their appraisals of energy futures could not be performed in a reflexive way without deliberative mapping. Yet, our experiment was also limited by some material constraints. While our four energy public groups have significantly broadened out the diversity of public appraisals of energy futures, many more remain, including artistic engagements, energy poverty groups, everyday practices, financial incentives and media and digital engagement (see [29,30,31]). With more time and resources the DDM experiment could have been further distributed to even more of these already existing collectives of public engagement with energy. Expanding the diversity and range of collectives and models of participation, and developing comparative analyses across different cultures and settings, is a key next step in the development of distributed deliberative mapping and approaches like it. In addition, our DDM experiments were necessarily streamlined, taking place over a reduced timeframe compared to previous deliberative mapping studies. This has made the method more accessible and distributed, but also constrained the amount of time for participants to consider the visions being appraised.

Like Parkhill et al. [7] we find that “the British public wants and expects change with regard to how energy is supplied, used and governed” (p11), particularly in relation to reducing our reliance on fossil fuels, a preference for sources of renewable energy, scepticism towards nuclear energy, a conditional willingness to share energy data, and a demand for equity and justice in energy transitions. The findings of our DDM study, however, would support a very different mode of governing to that imagined by such existing public appraisals of whole energy system futures. It departs from a dominant science-policy imaginary that prioritises eliciting ‘representative’ mini-public views to inform centralised decisions made by those managing ‘the transition’. We argue that DDM imagines, reveals and can support much more distributed modes of governing sociotechnical transformations, across spaces and scales. The DDM method can be extended in future research to involve many more distributed collectives across ‘the system’ (for example, through the use of digital technologies), which would be of relevance to actions and commitments not only by centralised decision-makers but also distributed system actors. In other words, the study we have reported on in this paper is a small-scale version of something much bigger. Compared to other existing approaches then, DDM stands to be a most promising method for supporting and operationalising one of the key findings of our study: public support for a more distributed energy system.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.erss.2021.102414.

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