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A systemic approach to mapping participation with low-carbon energy transitions

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Low-carbon transitions demand long-term systemic transformations and meaningful societal engagement. Most approaches to engaging society with energy and climate change fail to address the systemic nature of this challenge, focusing on discrete forms of participation in specific parts of wider systems. Our systemic approach combines comparative case mapping of diverse public engagements across energy systems with participatory distributed deliberative mapping of energy system futures. We show how UK public participation with energy is more diverse than dominant approaches posit. Attending to these more varied models of participation opens up citizen and specialist views, values and visions of sustainable energy transitions, revealing support for more distributed energy system futures that recognize the roles of society. Going beyond narrow, discrete understandings of communication and public engagement towards systemic approaches to mapping participation can provide plural and robust forms of social intelligence needed to govern low-carbon transitions in more socially responsive, just and responsible ways.

Transitioning to more sustainable and low-carbon energy systems has become a defining challenge of the early twenty-first century. Keeping increases in global average temperature to well below 2 °C as set out in the Paris COP21 climate agreement, while ensuring secure and equitable energy services, demands transforming energy systems on unprecedented scales. Many countries around the world have embarked on concerted programmes to steer such change, through a relative focus on technological, infrastructural and economic interventions[1]. It is increasingly recognized, however, that low-carbon transitions also depend on the meaningful engagement of society[2]. Societal engagement is varyingly seen as crucial to raising public awareness, exploring public support for low-carbon policies and technologies[3], shifting energy-related behaviours and consumption practices[4], through to underpinning deeper forms of citizenship and democratic accountability in governing energy transitions[5].

Programmes to engage society in industrialized nations and globally over the past two decades have seen some successes, but have not achieved desired breakthroughs in energy behaviour change (averaging at 7.4% reductions in energy use[6]), in public support for controversial low-carbon energy technologies or in institutional responsiveness to public values and equity issues[7]. A key reason for this is that most mainstream approaches to public participation and engagement with energy and climate change insufficiently address the systemic nature of the challenge. Existing approaches are compartmentalized, focus on discrete forms of engagement in specific parts of wider energy systems and tend to prescribe narrow meanings and metrics of success. For example, behaviour change studies focus on energy consumption and demand in everyday life, attitude surveys and deliberative processes tend to focus on public acceptability of new technologies and policies, whereas community energy initiatives engage citizens in becoming local producers of renewable energy[8]. Through adopting narrow, discrete and highly partial perspectives on participation, many existing approaches thus fail to capture the diverse, multiple and interconnected ways in which publics engage with energy systems on an ongoing basis[8].

Recent advances in social science theories and methods question this evident fragmentation and offer new solutions. First, social theories and methods pertaining to public participation and engagement are undergoing a systemic turn. Recent conceptual developments in deliberative democracy[9], practice theory[10,11] and science and technology studies (STS)[12,13] are shifting from a mainstream view of public engagement as occurring in discrete isolated processes to develop a broader perspective on how diverse practices of participation interrelate and connect up across wider systems. Second, such work shows public engagements to be both diverse and socially constructed. What people and groups in society think and do about complex issues such as energy and climate change has been shown to be powerfully shaped by the particular sociomaterial settings and practices through which they engage, how they are organized and by whom[8,14–17]. Furthermore, these settings and forms of participation are rapidly multiplying as people become more connected with energy systems through distributed forms of energy generation, energy demand response, the rise of digital and smart energy technologies, and so on. Understanding participation with energy transitions in the current era therefore needs to broaden out to map diverse engagements across wider systems, and open up to how different models and practices of participation shape outcomes[12,18].

Recent research has built on developments in national-scale public participation processes on particular energy technologies[19], to elicit public attitudes and values on alternatives for energy system change[20,21]. This work has taken an important step in moving to a 'whole systems' perspective, identifying public values that should guide future energy system transitions[22]. However, while opinion surveys and small-group deliberative events allow selected invited public views on energy system transformations to be elicited, they each constitute a discrete, particular and highly formalized model and setting of participation that shapes outcomes. This particular 'whole system' approach to public involvement thus does not directly attend to or trace the wider system of engagements, that is, the diverse, ongoing, already existing practices and settings through

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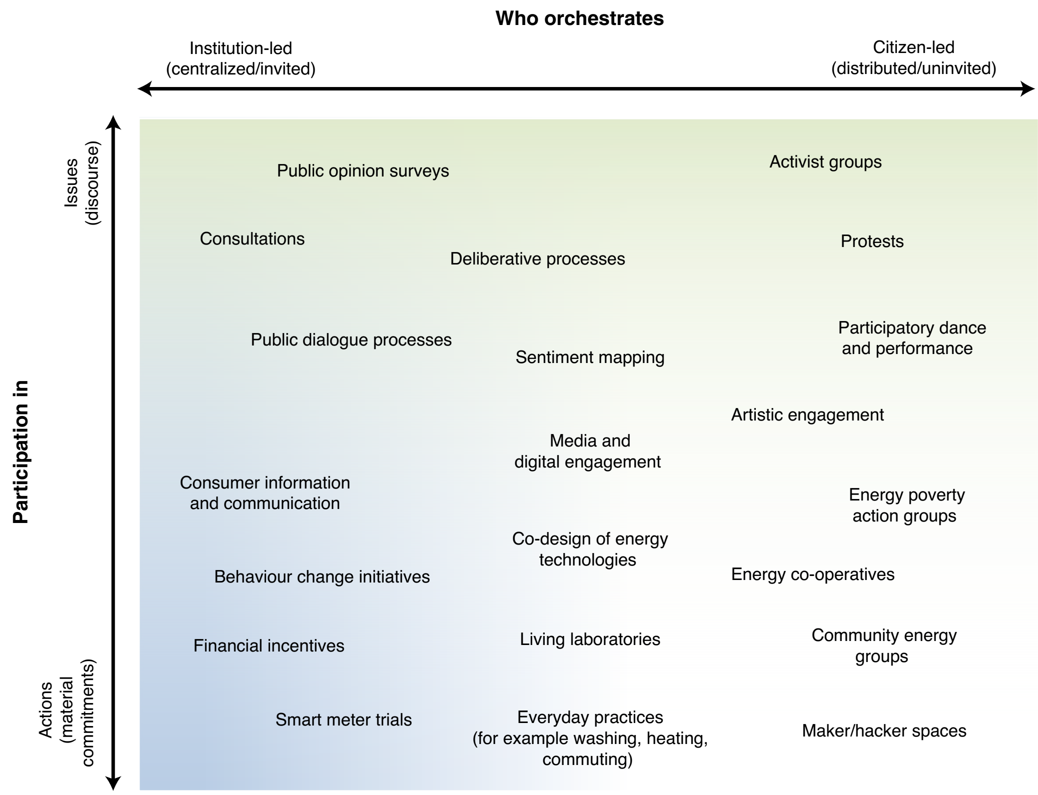

Fig. 1 | A heuristic framework for mapping diversities of public participation across wider systems. Based on the results from mapping participation in the UK energy system, 2010–2015 ($n = 258$ cases in total). Models of participation are mapped on two dimensions on the basis of the degree to which they are predominantly (1) institution-led or citizen-led and (2) involve participation in issues or actions. Some smaller categories identified in the corpus with low (n) values are not included in the figure, namely formal political processes ($n = 3$); media discourse ($n = 1$); community participation ($n = 1$); social impacts ($n = 3$); public perceptions research ($n = 2$) and action research ($n = 1$).

which publics are engaging with, valuing, imagining and acting on energy system transitions in different ways.

In this article, we present a systemic approach that seeks to do this, serving as a complement to these recent developments by building on the aforementioned advances in social science theories and methods. It comprises two combined mapping methods that we have developed: a method to map broader diversities of already existing public engagements across energy systems, and one based on this that opens up to these diverse models of participation and energy visions through a distributed deliberative process involving citizens and specialists in appraising sustainable energy futures.

Mapping public participation across energy systems

New methods are emerging that can assist with mapping the increasing multiplicity of public participation and citizen engagements across energy systems, including digital methods[23] through to forms of meta-analysis and comparative case analysis[8]. The first part of our systemic approach draws on these methods in addition to a systematic review methodology developed by the UK Energy Research Centre (UKERC)[24]. Our comparative case mapping method was developed and applied in a study that produced a comprehensive dataset of 258 cases of UK public participation and engagement with energy occurring between 2010 and 2015 (Methods). Opening up to diverse practices of participation according to the aforementioned systemic and practice-based theories meant that these cases and their documentation spanned academic and non-academic settings, as further explained in Methods.

This mapping across a whole national energy system has shown how forms of public participation and engagement with energy transitions are highly varied and diverse in terms of who participates (not limited to general aggregate populations, consumers, users, activists, communities, active citizens and householders), what they participate in (ranging from everyday engagements with energy efficiency and smart technologies in the home through to larger-scale technologies such as renewables, hydraulic fracturing and nuclear power) and how they participate (spanning formal surveys, consultations and deliberative processes to forms of protest, digital engagement and everyday practices)[25,26]. Furthermore, our prior analysis has demonstrated how these seemingly disparate engagements do not occur in isolation, as indicated by many existing theories and methods. Rather, they continually interrelate and shape each other as part of wider 'ecologies of participation' across energy systems[25].

In this article, we move beyond considering these methodological and empirical developments in their own right, to show how our comparative case method for mapping participation and tools like it can work in conjunction with and shape the design of new engagement processes as part of a systemic framework for participation in sociotechnical transitions. To this end, Fig. 1 presents the results of a new synthetic analysis of our comparative case mapping dataset in the form of a heuristic mapping space. We suggest this can be used to inform the design and analysis of participation practices from a systemic perspective, as we demonstrate with the second part of our systemic approach below.

Synthetic coding analysis of the mapping dataset (Methods) revealed two key axes along which models of participation vary in Fig. 1. The first centres on who orchestrates participation[8,17], ranging from more institution-led or centralized to more citizen-led or distributed participation practices (otherwise termed 'invited' to 'uninvited' public engagement[27]). The second axis spans from participation practices that emphasize the expression of views about energy-related issues (discursive commitments) through to those that are more action-orientated (foregrounding material commitments and change)[14,28]. It is important to note that these axes are not binary or absolute distinctions but rather are continua along which forms of participation vary, are hybrid and coproduced[8,29]. Figure 1 thus offers a heuristic to map different qualities of public participation and engagement across systems, notably the models and practices of participation, who orchestrates and frames the process and what gets produced.

Some of the most prevalent models of participation and engagement identified in the comparative case mapping are situated on the left-hand side of Fig. 1, including public opinion surveys ($n=41$), consultations ($n=23$), deliberative and public dialogue processes ($n=35$) that elicit public views on energy issues (in the top-left part of Fig. 1), and behaviour change initiatives ($n=50$) inclusive of consumer engagement and smart meter trials, which emphasize citizen-consumer actions (in the bottom-left part of Fig. 1). This reflects an emphasis on invited institution-led public engagement by government, business or scientific organizations across the UK energy system. While not exclusively so, cases in these parts of the map are most often framed in terms of public acceptability of policies and technologies as well as behaviour change[30].

What is particularly striking when visualizing the mapping data in Fig. 1 is the way it broadens out beyond institution-led public involvement to more citizen-led and grassroots forms of engagement and action. In the top-right part of Fig. 1 this includes citizen-led models of public involvement in debating energy issues, which are fewer in number but tend to develop alternative visions of energy futures and challenge existing policies through forms of activism and protest ($n=16$) and arts-based engagement ($n=9$). Citizen-led forms of participation that are more action-orientated appear in the bottom-right part of Fig. 1, including more 'bottom-up' grassroots citizen action in community energy and energy cooperatives ($n=33$), energy justice groups ($n=2$) and makerspaces ($n=1$). Figure 1 also highlights newly emerging practices of participation and forms of engagement that blur distinctions on the two axes, including digital engagement ($n=6$), sentiment mapping ($n=4$), codesign ($n=12$), living laboratories ($n=1$) and increasing recognition of everyday practices as a mode of engagement ($n=14$). It is important to note that the models of participation presented in Fig. 1 are not absolute and can overlap and transform over time (one example being where a more issue-orientated fracking protest morphed and transformed into a more action-orientated community energy initiative)[25].

The analysis presented in Fig. 1 provides evidence to support the aforementioned conceptual relationship between the settings and practices of participation, how they are organized and by whom, in shaping what gets produced. Our analysis shows that broadening out to a wider diversity of citizen-led engagements can identify and reveal additional public perspectives, visions and concerns likely to be missed by instances of participation located on the left-hand side of Fig. 1. This was evident across many issues in the mapping dataset, including those relating to smart technologies, renewables and hydraulic fracturing (fracking). To illustrate this using the last example, cases in the comparative case mapping located in the top-left part of Fig. 1—including public opinion surveys and deliberative processes (cases 5 and 11, Supplementary Table 1)—were framed in terms of risks and effects from fracking to the environment and health, and how impacted communities might be best engaged and compensated. Cases situated in the top-right part of Fig. 1—ranging from media discourses through to forms of activism and protest (cases 2, 22 and 25, Supplementary Table 1)—revealed additional public concerns over equity, the broader direction of energy transitions, the underlying purposes of fracking and who stands to benefit and bear the risks (see also ref. [31]). Our mapping thus further confirms the findings of earlier research, which shows citizen-led

Table 1 | Six sociotechnical visions of energy system futures appraised by participants in DDM workshops

Future energy vision	Summary description
Business as usual	A vision of a future where the energy system is similar to how it is now
Large-scale technologies	A vision of a future where new technologies are developed and deployed to reduce carbon dioxide emissions
Deliberative energy society	A vision of a future where the public has much more of a say over what happens with the energy system
Smart tech society	A vision of a future where 'smart' technologies are used to make the energy system more connected and efficient
Local energy partnerships	A vision of a future where people work together in partnership for localized energy systems
Off-grid energy communities	A vision of a future where communities live 'off-grid'

and 'uninvited' forms of participation to often include alternative and more radical visions of energy system change, placing greater emphasis on sociocultural change as well as alternative models of growth and social progress[5,8].

This shows that broadening out to map across wider systems of participation can provide additional social intelligence about public values and concerns that may generate resistance to, or suggest alternative, low-carbon energy transitions. Our comparative case mapping has also identified emergent models of participation and citizen action beyond incumbent institutional framings that, once revealed, can be recognized and further catalysed through policy interventions to assist low-carbon transitions. Such mappings can complement and add to existing engagement approaches by providing more systemic and plural evidence to inform governance and innovation processes. They can also inform and shape the development of new distributed practices of public participation across systems, as demonstrated by the second part of our systemic approach.

Distributed deliberative mapping of energy futures

Mapping existing and past systems of public participation with energy transitions does not replace the need to create new spaces of participation that can imagine, appraise and anticipate alternative energy system futures. Existing social scientific models of engagement for eliciting public views on energy system transitions are firmly located in the top-left part of Fig. 1, most often taking the form of professionally facilitated institutionally framed small-group deliberative exercises or larger-scale public surveys[20,32,33]. While some of these processes have been reflexive about the framing of issues and energy futures under discussion (see, for example, ref. [21]), such thinking has rarely extended to the models of participation used, which have remained relatively fixed (although for important exceptions see refs. [12,16,34]). The aforementioned advances in social science theories and comparative case mapping results demonstrate how the specific model of participation—that is, the settings and practices through which citizens engage, and how they are formatted and by whom—plays a fundamental role in shaping public views and actions on energy futures. To account for this, in the second part of our systemic approach we undertook a distributed deliberative process that opened up to and actively experimented with varying models of participation as identified across the mapping space in Fig. 1.

Deliberative mapping (DM) is an established participatory multicriteria appraisal method[35] that has been successfully applied in appraising future courses of action on complex, uncertain and contentious issues such as radioactive waste management[36], climate change[37], medical health technologies[38] and GM crops[39]. DM symmetrically involves citizens and specialists in: framing the issue or problem; considering alternative courses of action (options) for addressing it; developing criteria by which to appraise the options; assessing the performance of the options against the criteria under optimistic and pessimistic assumptions and weighing the criteria in terms of relative importance (Methods). The established DM method seeks to open up the range of actors and perspectives involved by including representative groups of citizens as well as specialists (the latter from academic, government, business and non-governmental organizaion sectors) in small-group deliberative workshops[35]. DM is particularly suited to exploring future energy system change as it seeks to open up issue framings, alternative visions and provides plural and conditional outputs on the performance of contending transition pathways[40].

The established DM method adopts a deliberative model of participation, grounded in Habermasian discursive ethics on the basis of equality of inclusion and participant expression mediated by a professional facilitator[35,41]. In the current study, we undertook a DM process on sustainable energy futures in the UK that was based on this established format involving a lay citizen group and a specialist group, but went further in opening the DM approach up to alternative models of participation identified in the first comparative case mapping part of our systemic approach (see Methods for further details). We call this further development of the DM method 'distributed deliberative mapping' (DDM). Whereas the established deliberative model of DM is situated in the top-left part of Fig. 1, we enabled DM to also be undertaken in three already existing groups, organized according to alternative models of participation, associated with the other three quadrants of Fig. 1.

These additional settings of participation in the DDM process included: a smart energy trial according to a market research model of participation involving participants as consumers (bottom-left part of Fig. 1); an activist group campaigning on energy and climate change issues who ascribed to a more autonomous and non-hierarchical model of participation (top-right part of Fig. 1) and a community low-carbon innovation group closely associated with a grassroots innovation model of participation and community development (bottom-right part of Fig. 1). The participants in the activist and grassroots community settings took a lead in designing and facilitating their own DDM process, according to their established model of participation and in keeping with their citizen-led position in Fig. 1. It is important to note that the selection of these groups did not seek to achieve geographic representation across different regions of the UK. In keeping with the aforementioned conceptual basis of our systemic approach, they were selected to be reflective of the different models of participation evident across the UK as identified in the first comparative case mapping part, which in itself achieved national coverage (Methods and Supplementary Fig. 1).

DM is flexible in allowing all participants to develop their own options, criteria, option performance scores and weightings[35]. As a starting point for discussion a broad framing of 'sustainable energy futures in the UK' was formed and the six diverse visions (options) summarized in Table 1 were developed and provided to participants based on existing visions of UK energy system transitions, namely: (1) business as usual; (2) large-scale technologies; (3) deliberative energy society; (4) smart tech society; (5) local energy partnerships and (6) off-grid energy communities (see Supplementary Fig. 2 for a more detailed version of these energy visions, shown in the format presented to participants). These visions were explicitly sociotechnical, opening up beyond technical aspects to encompass alternative social dimensions and futures (including governance arrangements,

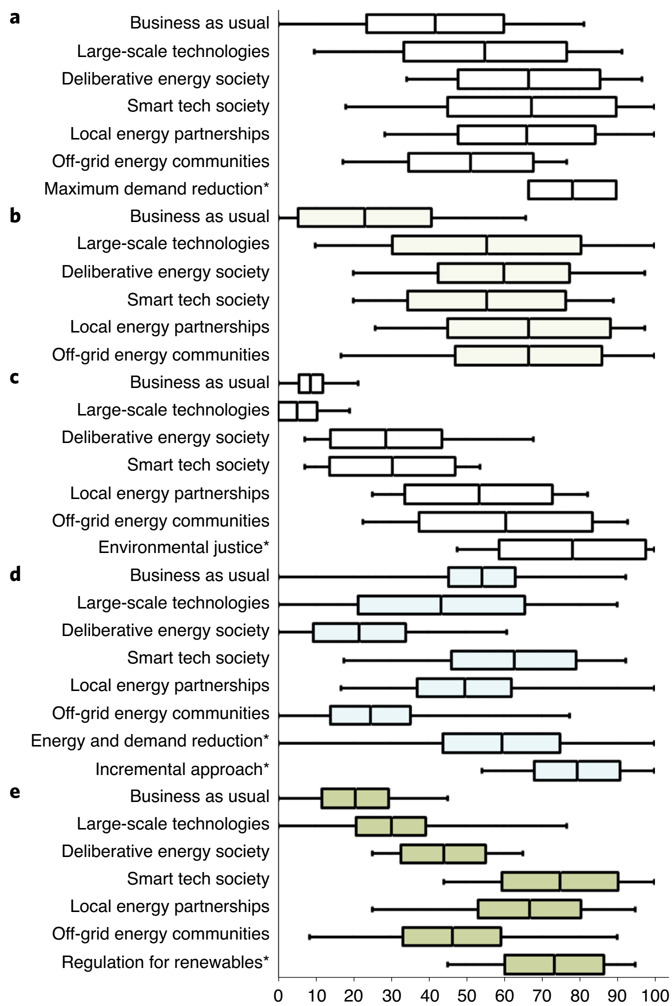

Fig. 2 | Distributed deliberative mapping appraisal maps of energy vision performance. a–e, Showing the final rankings of energy vision performance as appraised by specialists ($n=7$) (**a**), deliberative citizens ($n=9$) (**b**), activist citizens ($n=6$) (**c**), grassroots innovator citizens ($n=11$) (**d**) and consumer citizens ($n=8$) (**e**). 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 (highest and lowest values) in vision performance under optimistic and pessimistic assumptions. The *x* axis is a relative scale from 0 (lowest performance) to 100 (highest performance). An asterisk indicates additional options developed and appraised by specific groups.

equity and models of growth) that are often excluded from technical and participatory appraisals of energy system change[2,42].

Each of the five groups (total $n=41$) engaged in all five steps of the DM process (Methods). Participants first explored the problem of sustainable energy futures before discussing the visions and in some groups adding their own self-defined visions. The groups then developed criteria to judge the performance of the different energy visions. They then appraised the visions against the criteria where individual participants gave two scores for each vision under each criterion (to reflect vision performance under optimistic and pessimistic assumptions). Finally, participants in each group weighted their criteria in terms of relative importance. The appraisal scores, criteria and their weighting for each participant and DDM group were subject to multicriteria mapping analysis (Methods) producing overall maps of vision performance for each group as shown

Table 2 | Example quotations from DDM group appraisals of sociotechnical energy visions

Technical feasibility
A. "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" (specialists group participant, on business as usual)
B. "Carbon capture and storage, it just isn't there so it's not actually going to be possible for 20 or 30 years" (activist citizens group participant, on carbon capture technology under large-scale technologies and local energy partnerships)
C. "Most of the technology that's needed to run a smart tech society is already in everybody's cell phone" (deliberative citizens group participant, on smart tech society)
D. "The school solar panel campaign is already being rolled out, home solar panels getting reduced tariff, it's already happening in varying scales" (deliberative citizens group participant, on local energy partnerships)
E. "A bit of a niche thing that is going to happen in a few places but probably not very relevant for others" (grassroots innovator citizens group participant, on off-grid energy communities)
Carbon reduction
F. "Best case scenario, utterly impossible, worst case scenario is even worse!" (activist citizens group participant, on business as usual)
G. "Effectiveness of carbon savings and the riskiness of it… sticking with business as usual is a very risky scenario" (grassroots innovator citizens group participants, on business as usual)
H. "Same with capture and storage, it's not proven. Fusion… 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" (specialists group participant, on large-scale technologies)
I. "There's more emphasis on energy efficiency which is important, I don't see this vision is necessarily at odds with meeting the carbon targets… it depends on what people prioritize" (specialists group participant, on deliberative energy society)
J. "Smart tech and off-grid scored the two highest… [because they are] the only ones which say that energy is almost entirely supplied by renewable energy" (specialists group participant, on smart tech society and off-grid energy communities)
Environmental impacts
K. "I think it's generally accepted that we're going in the wrong direction!" (deliberative citizens group participant, on business as usual)
L. "If you get people on board and get them interested, then I think it brings on greater environmental possibilities [and] improvements because you get more understanding by a wider range of people" (consumer citizens group participant, on deliberative energy society)
M. "Pollution, land use, resource use and so the two lowest I've got there is large-scale tech and smart tech and I score them very low because what I would call the fetishization of carbon, so smartphones are not intrinsically great, they use an awful lot of resources and you can imagine an awful lot more tech actually going the same way" (specialists group participant, on large-scale technologies and smart tech society)
N. "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" (deliberative citizens group participants, on local energy partnerships)
O. "Imagine if everyone lived off-grid and there was a rule, you can't burn anything, that should improve the environment, but it probably won't improve your life" (consumer citizens group participant, on off-grid energy communities)
Economic efficacy
P. "A lot of money, 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" (consumer citizens group participant, on business as usual)
Q. "Large-scale technology: there is an issue that is the current model actually going to fund it?" (specialists group participant, on large-scale technologies)
R. "It could be high because actually 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" (specialists group participant, on smart tech society)
S. "I think it's pretty much guaranteed to be cost effective… because it's a community deciding what it's going to do and if it doesn't believe that there is a payback for the community then it won't do it" (deliberative citizens group participant, on local energy partnerships)
Political practicality
T. "Fusion and large-scale biofuels are, I feel are less credible, so more difficult to transition to those" (specialists group participant, on large-scale technologies)
U. "Coming to a decision about moving to renewables maybe a bit difficult, there's lots of different opinions" (deliberative citizens group participant, on deliberative energy society)
V. "I think that in a good situation, the majority will take it on board and it will be very efficient but I think I was further down in the worse scenario… Because there will be people who don't understand the technology" (consumer citizens group participant, on smart tech society)
W. "You've got in theory a more democratic build up here because they're local, so you're negotiating, reaching decisions" (deliberative citizens group participant, on local energy partnerships)
X. "And off-grid, 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" (specialists group participant, on off-grid energy communities)
Public acceptability
Y. "Business as usual, it's not going to involve people, it's just going to be carried on with the companies making rules and nothing's going to change" (consumer citizens group participant, on business as usual)

Continued

Table 2 | Example quotations from DDM group appraisals of sociotechnical energy visions (continued)

Z. "It's unlikely to be in my back yard" (grassroots innovator citizens group participant, on large-scale technologies)
AA. "Obviously here… you've got members of the public that are active participants" (specialists group participant, on deliberative energy society)
BB. "[We] are going to have to try and find public buy-in but in terms of how important for me personally is public acceptability, I'd rather just get on with it regardless myself" (grassroots innovator citizens group participant, on deliberative energy society)
CC. "We've got the phones, we've got the computers, and this is just the next step isn't it? We're already there" (deliberative citizens group participant, on smart tech society)
DD. "It's a bit of a Marmite"… "It will be quite a big divide"… "But it's going to be a minority who do" (deliberative citizens group participants, on off-grid energy communities)
Societal fairness
EE. "I don't see climate targets being met so I see the damage costs of climate change being experienced and those not being equally experienced, those will hit the vulnerable in society the hardest" (specialists group participant, on business as usual)
FF. "…you could see a scenario with that one where they can have very high prices and there's no regulation of that, it's not clear" (specialists group participant, on large-scale technologies)
GG. "I think it's quite fair, purely because I like the idea of the public being active members, partners in the decision making and I think that really could be fair in that sense" (deliberative citizens group participant, on deliberative energy society)
HH. "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" (deliberative citizens group participant, on local energy partnerships)
II. "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" (activist citizens group participants, on off-grid energy communities)

Quotes are organized by the main appraisal criteria themes. For each quote, the group affiliation of the participant(s) that made the statement, and the energy vision being referred to, are noted in parentheses

in Fig. 2. In addition to this quantitative analysis, the reasonings behind these appraisals produced a wealth of qualitative data. Table 2 provides select example quotations pertaining to the appraisal of energy visions by the different DDM groups, organized by the main appraisal criteria themes (see Supplementary Table 2 for additional representative quotations).

DDM appraisal maps (Fig. 2) show distinctive vision rankings and patterns of internal ambiguity, although broader patterns of vision performance are evident across all groups. In terms of the six core visions appraised, the mean rank order across the five groups reveals three tiers of overall core vision performance. The two lowest ranking visions were business as usual (ranked lowest by deliberative citizens, consumer citizens and specialists, second lowest by activist citizens and fifth lowest by grassroots innovator citizens, for example quotes A, F, G, K, P, Y, EE in Table 2) and large-scale technologies (ranked lowest by activist citizens and second lowest by consumer citizens, for example quotes B, H, M, Q, T, Z, FF in Table 2). A strong finding from across most DDM groups is the urgent need to shift away from the incumbent energy system (for example, quotes A, F, G, K in Table 2), coupled with concern amongst some groups over a reliance on techno-fixes and technologies such as bioenergy with carbon capture and storage, nuclear and advanced biofuels (for example, quotes B, H, Q, T in Table 2).

The two middle ranking visions (Fig. 2) were deliberative energy society (ranked second highest out of core options by specialists but lowest by grassroots innovator citizens, for example quotes I, L, U, AA, BB, GG in Table 2) and off-grid energy communities (ranked highest out of core options by activist citizens and second highest by deliberative citizens but second lowest by grassroots innovator citizens and specialists, for example quotes E, J, O, X, DD, II in Table 2). The two highest ranking visions were smart tech society (ranked highest out of core options by grassroots innovator citizens, consumer citizens and specialists, but second lowest by deliberative citizens, for example quotes C, J, M, R, V, CC in Table 2) and local energy partnerships (ranked highest by deliberative citizens and second highest out of core options by activist citizens and consumer citizens, for example quotes D, N, S, W, HH in Table 2). These patterns of option performance across all groups in Fig. 2 show citizen and specialist support for a more distributed future energy system that pays greater attention to the roles of society and inclusive modes of governing (for example, quotes D, J, L, N, R, S, W, AA, GG, HH in Table 2). The additional visions developed by specialist, activist, grassroots innovator and consumer groups performed highly in comparison to core visions in all cases (Fig. 2a,c,d,e).

These DDM results provide further evidence that the model of participation, and the formatting of practices through which people participate, plays a crucial role in shaping their perspectives on alternative energy futures. While there are some specific differences in vision rankings, there is consistency between deliberative citizen and specialist group appraisals (Fig. 2a,b) in terms of the overall pattern of option performance and variability ranges between individual participants. This is especially noteworthy because of the considerable differences in experience and expertise between specialist and lay public participants in these two groups. It suggests very strongly that models of participation matter. The deliberative model and setting of participation in the established DM method was one of the main commonalities between these two groups (Methods), and thus had a conditioning affect on the appraisal outcomes produced.

Opening up to the consumer, activist and grassroots innovator groups, each with alternative already existing models of participation, created different patterns of vision performance compared to the established DM method (Fig. 2c–e). The variability ranges between optimistic and pessimistic scores are smaller for the most part and differences in vision rankings are more pronounced. Engaging with these three already existing models of participation in DDM introduced a greater diversity of perspectives on vision performance. Each group identified one core vision as the stand-out highest performing: off-grid energy communities for the activist group, and smart tech society for the grassroots innovation and smart consumer groups.

Opening up beyond the established DM format to alternative models of participation also introduced a greater diversity of criteria by which to judge future energy system transitions, as shown in Table 3 (see also Table 2 and Supplementary Table 2 for representative quotations associated with these criteria and their application in appraising energy visions). Of particular note in this regard is the activist setting, which introduced a wider range of equity and

Table 3 | Criteria to appraise alternative energy futures developed by the five DDM groups

Criteria	Deliberative citizens	Activist citizens	Grassroots 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%)

Individual criteria produced by participants were grouped into criteria clusters on the basis of qualitative analysis. In cases where a criterion overlapped with another criteria cluster, the aspect emphasized during the appraisals was used to categorize the criterion. Mean group weightings for each criteria cluster are given in parentheses, representing the relative importance assigned to each criteria cluster by each DDM group.

justice-based criteria as well as concerns over public acceptability compared to deliberative and specialist groups, with greater weighting being placed on criteria pertaining to social dimensions of energy system transitions. These DDM findings indicate that experimenting with alternative models of participation and democracy should become a key design concern and explanatory variable in processes of public engagement with energy and climate change, rather than being something to be held constant at all costs.

Transforming participation for just transitions

As the world moves into a low-carbon era, urgent policy and technological developments are placing increasing strain on established relations between science, politics and society. Under these conditions the governance of low-carbon transitions needs to be responsible, inclusive of and responsive to societal values, public concerns and human needs[5]. This is about more than public acceptance and behaviour change. It is crucial to renewing the social contract between citizens and governing institutions[22] and accounting for 'the public interest' in ways that address human needs and ensure more equitable energy transitions[7,43]. Mainstream approaches to eliciting public views, such as surveys and deliberative processes, are of undoubted value[19,20], but underplay and can exclude an ever-growing multiplicity of public engagements with energy and climate change, fuelled by the digital revolution, the rise of social media, citizen-led mobilizations, moves to more distributed energy systems and so on[14,44,45].

Our approach seeks to attend to this multiplicity while complementing these existing approaches of invited public elicitation. This has been achieved through developing and combining two mapping methods to form a systemic approach to participation and accounting for public values and actions in national energy system transitions. In the first part, our comparative case mapping findings provide conclusive evidence of the increasing diversity of public engagements with energy. Through broadening out to include emerging or excluded models of participation—from digital democracy to everyday social practices, and from citizen-led forms of activism to grassroots citizen actions—our study demonstrates how systemic mapping approaches can provide more comprehensive evidence on the diversity of public views and reveal excluded or unrecognized spaces of engagement including potential new sources of low-carbon action. Such mappings can thus help reveal exclusions, omissions and uncertainties in evidence about energy publics. Our systemic mapping approach and heuristic presented in Fig. 1 helps to operationalize the idea of public participation with energy and climate change being ongoing and multiple, and not only institution-led but also citizen-led. The significance and relevance of this is further emphasized by the recent and ongoing emergence of diverse climate change engagements ranging from Extinction Rebellion protests and Fridays for Future school strikes, to Citizens' Assemblies on low-carbon futures, all of which can be mapped by the broader framework we have presented in Fig. 1.

In the context of imperatives to accelerate the decarbonization of energy systems, this can in turn support more ongoing and responsive systems of governing, where public values and actions are not seen as fixed but in flux and continually emerging. Here a key challenge becomes one of cultivating new forms of institutional reflection and responsiveness[30,46] to the diverse forms of public value, visions and actions that already exist across energy systems and across cultures. Approaches to mapping participation can form the basis for new engagement architectures, such as observatories that oversee and map on an ongoing basis how publics and societies are engaging with energy and low-carbon transitions at national, international or subnational scales[47]. In addition to oversight of technological and policy developments, such observatories can play a vital role in translating this social intelligence to help ensure innovations, policies and engagement practices that seek decarbonization are also responsible, just and sustainable in the longer-term (for similar proposals made in the context of gene editing, see refs. [48,49]).

The formation of new engagement architectures does not reduce the need to cultivate new forms of participation with energy and climate change. Indeed, as the findings of our DDM study show, systemic mappings can inform and enhance the design of anticipatory public engagement on energy and low-carbon transitions. Opening up an established deliberative multicriteria appraisal method to alternative models of participation identified in our comparative case mapping (Fig. 1), has served to reveal additional societal visions, value-based criteria (Table 3) and perspectives on the performance of alternative future pathways for energy system transformation (Fig. 2). While the value-based criteria generated are broadly comparable, our DDM results differ from the largely centralized policy focus of other large-scale analyses of public views (for example, refs. [20,22]) to also emphasize more distributed patterns of governance and social transformations in energy system change. Deliberately experimenting with alternative models of participation and modes of orchestration in DDM has provided some of the first evidence in the energy field that the practices and formats of participation matter to how energy futures are appraised[50]. This highlights the need for future public participation experiments to be reflexive and inclusive not only about issue framings and process participants, but also about how the models and practices of participation are formatted and framed[12,16,45].

Faced with complex, uncertain and systemic challenges of energy and climate change, opening up participation in this way can reveal important social uncertainties and differences between contending interests, while providing recommendations on areas of commonality[18]. In this sense the DDM has identified specialist and public support for more distributed energy system futures that pay greater attention to the roles of society. In sum then, our systemic approach shows how methods for mapping participation, publics and sociotechnical transitions—and the mapping of system-wide energy participation coupled with DDM in particular—can provide more plural and robust forms of social intelligence needed to govern low-carbon transitions in more socially responsive, just and responsible ways. This points to the future potential of such mapping participation approaches in other national and international settings, in longitudinal analyses and also beyond the fields of energy and climate change.

Methods

A systemic mapping participation approach. The systemic approach to participation in sociotechnical transitions presented in this article comprises two interrelated mapping methods. The first, comparative case mapping, is an innovative form of comparative case analysis for mapping diverse forms of participation and public engagement across wider systems. The second, DDM, further develops an established participatory multicriteria method for appraising alternative futures and contending courses of action in addressing complex and uncertain public problems, such as low-carbon energy transitions. The emphasis of both mapping methods is on 'opening up' to diversity and difference, as well as identifying areas of similarity, with respect to constitutive elements associated with a particular object of attention, such as public participation or energy transitions. In both methods, the term 'mapping' involves framing, identifying, arranging and visualizing constitutive elements and their relations to one another around an object of analysis. In both instances, mapping is a form of knowledge-making and representation as well as an open-ended research method. For comparative case mapping, the object being mapped was the collective practices through which publics participate in energy system transitions, based on mapping analyses by the research team, database searches, documentary evidence and oversight of an advisory group. Whereas in DDM the mapping object was the performance of different options and future pathways for addressing public problems, in this case sustainable energy transitions, with mapping being conducted through the inclusion of diverse experts, stakeholders and publics. Developing and closely integrating these methods for mapping systems of participation and for participatory mapping of system change forms our new systemic approach to participation and accounting for public values and actions in national energy system transitions.

Mapping participation: comparative case analysis. *The mapping participation method.* The mapping of system-wide energy participation was informed by a systematic review methodology developed by the UKERC[24]. This methodology draws on the protocols developed in medical systematic reviews to enable a systematic review of the academic literature around a clearly defined topic area. Our method differed from this in several important ways. First, to map diverse forms of participation according to the systemic and practice-based theories set out in the beginning of this article, our mapping included not only academic literature but also relevant reports, news articles and websites in the public domain. As we were aware that the academic literature had clear partialities in coverage of particular kinds of public participation with energy over others, and that the time lags in academic publishing cycles meant that more recent cases might not be included, it was important to be able to include instances of participation that had been documented in other ways. Our criteria for inclusion of cases not from the academic literature were that there needed to be enough documented evidence of the case for it to be possible to analyse the case according to the key categories from our conceptual framework:[8,25] namely, the who (that is, participants), the how (that is, model) and the what (that is, object) of energy participation. All of the cases collected were (re)analysed using this framework, including academic studies and instances of engagement encompassed by our framework's open definition of participation (as stated in 'Searching and producing the corpus' below). This leads to the second way in which our mapping participation approach differed from the standard UKERC systematic review methodology. To include cases beyond the academic literature, we used Web of Science, Scopus, Google Scholar and Google for our searches so that we found a wider diversity of material. The Web of Science and Scopus searches were exhaustive. Due to the much higher number of results produced by Google Scholar and Google, for these searches the first four pages of results were reviewed and the researcher only proceeded further if relevant cases were still found after four pages. The mapping participation comparative case analysis followed a structured process, informed by aspects of systematic review methodology and a practice-based coproductionist theory of participation[12,25], comprising the following steps: (1) scoping the framework for analysis and search terms; (2) expert panel feedback on the approach; (3) searching and screening of academic and grey literature based on synonyms for the model (how), participants (who) and object (issue) of participation; (4) documentary analysis of 258 cases and (5) in-depth case study analysis of a subset of 30 cases.

Searching and producing the corpus. The search terms used to identify relevant papers and other materials were based on the structure of 'UK' + 'energy' + 'public' + 'participation'. However, as the corpus we were building mainly consisted of interpretive qualitative studies, it was necessary to use a large number of different synonyms in the searches to pick up on different forms of and approaches to public participation and engagement. For example, synonyms for energy included 'electricity', 'heat', 'transport' and 'biofuels'; synonyms for public included 'user', 'stakeholder', 'consumer' and 'citizen'; synonyms for participation included 'engagement', 'dialogue', 'survey' and 'protest' and synonyms were used for different parts of the UK. A full list of synonyms can be found in the full technical report of the mapping participation analysis[51]. The synonyms used were systematically identified through an initial reading of relevant academic literature on energy participation and advice from the project's expert advisory panel during the scoping phase of this process. To assess a case's relevance, the researcher read each paper, report or website to check whether it fitted our study's open definition of energy participation as: 'heterogeneous collective practices through which publics engage in addressing collective public problems (in this case 'energy-related' issues), whether deliberately or tacitly, which actively produces meanings, knowings, doings and/or forms of social organization'. Cases of participation in the corpus achieved national coverage across different regions of the UK (Supplementary Fig. 1).

Comparative case analysis. The final corpus of 258 cases of public participation and engagement with energy (Supplementary Table 3) was coded by the researcher according to the who, what and how of energy participation in addition to categories such as regions in the UK, the issue domain the case belonged to, methods used, institutional settings and aims. This coding was cross-checked for consistency by the principal investigator of the project. A more fine-grained analysis was conducted on a subset of 30 cases (Supplementary Table 1) from the large corpus to gain a deeper understanding of diverse cases of participation, their productivities in terms of public views and actions, how they interacted with each other and with the broader energy system. We have reported separately on aspects of this analysis pertaining to the diverse forms of public participation and engagement with energy transitions and how they interact as part of wider ecologies of participation that make up energy systems[25,26]. Instead of reporting on different dimensions (such as the who, what and how) of participation separately, in this article we present a synthetic analysis conducted across the whole dataset and qualitative coding framework. Synthetic coding analysis of the mapping dataset revealed two key axes of difference along which practices of participation vary: (1) who orchestrates the process (ranging from institution-led to citizen-led); and (2) what is participation for and what gets produced (ranging from the expression of views about energy-related issues through to material commitments and actions). Codes relating to models of participation, who orchestrates and frames the process and what gets produced in terms of public views and actions, were thus synthesized through interpretive analysis to produce the heuristic mapping space presented in Fig. 1, with models of participation plotted in relation to the two axes.

Visualization. The final stage of the comparative case mapping was to create visualizations of key trends and patterns observed in the cases studied, the main summary output from which is shown in Fig. 1, to help interpret and communicate the patterns of public participation and engagement with energy in the UK occurring between 2010 and 2015. This analysis and the heuristic mapping space presented in Fig. 1 informed and shaped the design of the second DDM part of our systemic approach.

Distributed deliberative mapping. *Visions.* To generate a diverse set of core visions (or 'options') for all participants to appraise, we undertook a review of diverse existing visions and scenarios of future energy transitions for the UK. This captured visions set out by: (1) the UK Government, including those within the Carbon Plan; (2) business, including those developed by the National Grid; (3) civil society, including those proposed by Greenpeace and (4) academia, including those used in earlier technical and social science research studies by the UKERC. The review identified five primary axes of difference between the visions. These consisted of technical assumptions about how energy would be produced, distributed and used, and social assumptions about growth and governance. In turn, each of these dimensions could be further differentiated. On the technical side, some visions emphasized energy produced by fossil fuels and nuclear power, for instance, while others emphasized renewable energy or more speculative technologies. Some visions assumed a centralized distribution grid run by large energy companies, whereas others assumed a decentralized grid. Similarly, some visions envisaged lowered demand through behavioural changes, whereas others predicted more energy efficient technologies, improving responsiveness to demand or more radical reductions in usage. On the social side, some visions assumed a status quo model of economic growth, while others assumed alternative models of growth that emphasized non-monetary values. In terms of governance, some visions assumed a market regulated by government with little involvement from citizens, whereas others assumed more government investment, less regulation, localized decision making or citizen-led decisions. An attention to the five axes of difference allowed us to then develop six very distinctive and contrasting core visions for appraisal: business as usual; large-scale technologies; deliberative energy society; smart tech society; local energy partnerships and off-grid energy communities (Supplementary Fig. 2). These were further illustrated by identifying the key actors or proponents and some real-world examples associated with each vision. They were brought together under an overarching framing of 'sustainable energy futures for the UK', with a 2050 time horizon.

Participants. Enrolment of DDM participants was appropriate to each of the five groups involved, comprising one group of specialists and four groups of citizens based on diverse models of participation in the UK energy system, namely deliberative citizens, activist citizens, grassroots innovator citizens and consumer citizens (main text). In keeping with the conceptual basis of our practice-based systemic approach to participation (outlined in the first part of this article), the selection of these groups foregrounded the models of energy participation evident across the UK as the main entry point and comparative basis for participant sampling. The selection of the four citizen groups was thus based on the findings of the UK-wide participation mapping summarized in Fig. 1, where each group of citizens was selected to represent one model of participation from one of the four quadrants of the mapping space. Enrolment of the specialist and deliberative citizen groups followed the established procedure used in conventional DM[35], identifying and inviting diverse senior energy specialists from across government, business, non-governmental organizations and academia around the UK ($n=7$) and selecting a quota of lay citizens reflecting key sociodemographic characteristics of the population of Norfolk ($n=9$). The lay citizen group was drawn from responses to an online survey administered by the research team through the Norfolk County Council 'Your Voice' citizens panel ($n=118$), which took account of age, gender and socioeconomic status variables as well as world issues of most concern (such as climate change, world population, poverty or an economic downturn), relationships with energy (such as smart meters, domestic renewables or paying bills) and preferred approach to an energy transition (expert, market or collectively led). The enrolment of the three already existing groups was different, involving the identification and invitation of already existing groups in society, on the basis of their pre-existing models of participation and the requirement for them to be active and accessible during the period of study, namely: a UK environmental activist group that formed in opposition to a multinational oil and gas company in London ($n=6$); a grassroots Mutual Society seeking to innovate and improve energy efficiency and reduce the carbon footprint of its community in Oxfordshire, UK ($n=11$) and members of a smart energy control technology trial in Wiltshire, UK ($n=8$).

Procedure. Taking place between January and July 2017, the five groups' appraisals all followed the same established five-step procedure used in conventional DM: issue framing, option creation, criteria development, option scoring and criteria weighting[35]. In the specialists group, which convened in a half-day workshop, the last four steps were conducted on an individual basis using laptops preloaded with Multicriteria Mapping software (available at www.multicriteriamapping.com). To reflect the groups' differing levels of experience with energy issues and their availability, the specialists group took place over the course of an afternoon, the deliberative citizens group took longer over the course of a full day, and the already existing groups each took place over the course of a morning or evening session. Much like the specialists' group, running the exercise with the already existing citizens groups was shorter owing to their previous engagement with the topic. By contrast, the deliberative citizens group was given an introduction to the topic such that lay expertise was developed. Crucially, however, the procedure in the already existing groups was collaboratively designed over an extended period of weeks before the events, with a key representative of each group structuring and then facilitating the DM method in keeping with the typical ways in which their groups would organize during their meetings and interactions. While the DDM process was framed overall as an exercise in appraising 'sustainable energy futures for the UK', each group appraisal began with a discussion of what the participants themselves felt the issues facing the energy system were. Moreover, while a set of six diverse core visions were developed by the research team for all participants to appraise (Supplementary Fig. 2), each group was also given the opportunity to develop additional, self-defined visions. The way in which criteria were developed differed between the groups. In the conventional DM groups, the specialists developed their criteria individually and the deliberative citizens developed their criteria as a group through a process of negotiated amalgamation, whereby individual criteria were clustered into common themes. The grassroots innovator and consumer citizen groups also opted for a negotiated amalgamation approach to criteria development, while the activist citizens developed theirs instead through collective deliberation. All groups scored the visions in the same way, using the established method——unique to DM——in which individual participants give two scores for each vision under each criterion, one under optimistic assumptions and one under pessimistic assumptions. This produces an uncertainty range for individual participants and allows for the analysis of a variability range across participants (as presented in Fig. 2). Finally, with the exception of the activist group that opted to weight all their criteria equally, individuals within each group weighted their criteria in terms of their relative importance (as shown in Table 3). While we had deliberately experimented with the format of DM, and indeed formally recognize this difference by giving it a distinct name (DDM), all of the core components of DM from previous exercises were present, that is issue framing, option definition, criteria development, option scoring, criteria weighting and participant review.

Analysis. The DDM process produced a wealth of quantitative and qualitative data, including the quantitative scoring of options and weightings of criteria and the audio-recorded and transcribed participant reasonings that underpinned those scores and weights. The data were analysed in accordance with established methods of DM analysis, including multicriteria mapping analysis and qualitative coding analysis[35]. Quantitative data relating to the scoring of options, criteria and criteria weightings were subject to multicriteria analysis using Multicriteria Mapping software to produce the energy vision performance maps presented in Fig. 2. Qualitative data were subject to qualitative coding analysis to establish key themes in the dataset, including in relation to participant-derived criteria as presented in Tables 2 and 3 and Supplementary Table 2.

Reporting Summary. Further information on research design is available in the Nature Research Reporting Summary linked to this article.

Data availability

Data and documentation for all 258 cases in the mapping participation comparative case analysis can be openly accessed at: https://doi.org/10.6084/m9.figshare.13850975. Data and material that support the findings of the DDM study are available from the corresponding author upon reasonable request after two years from publication of this article.

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Author contributions

J.C. led the research and its overall design as principal investigator. The comparative case mapping was led by J.C. with data collection and analysis being undertaken by H.P. with inputs from J.C. and T.H. All authors contributed to the design and data collection of the DDM, with analysis being led by J.C. and undertaken by R.B. Figure 1 was developed by J.C. and Fig. 2 was prepared by R.B. J.C. wrote the article with contributions from R.B., H.P. and T.H.

Competing interests

The authors declare no competing interests.

Additional information

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☒	☐	For Bayesian analysis, information on the choice of priors and Markov chain Monte Carlo settings
☒	☐	For hierarchical and complex designs, identification of the appropriate level for tests and full reporting of outcomes
☒	☐	Estimates of effect sizes (e.g. Cohen's *d*, Pearson's *r*), indicating how they were calculated

Our web collection on statistics for biologists contains articles on many of the points above.

Software and code

Policy information about availability of computer code

Data collection	Multicriteria Mapping (MCM) software (see https://www.multicriteriamapping.com) was used to assist with data collection from the specialist group participants in the Distributed Deliberative Mapping (DDM) process.
Data analysis	Distributed Deliberative Mapping (DDM) analysis was undertaken using Multicriteria Mapping (MCM) software (see https:// www.multicriteriamapping.com) .

For manuscripts utilizing custom algorithms or software that are central to the research but not yet described in published literature, software must be made available to editors/reviewers. We strongly encourage code deposition in a community repository (e.g. GitHub). See the Nature Research guidelines for submitting code & software for further information.

Data

Policy information about availability of data

All manuscripts must include a data availability statement. This statement should provide the following information, where applicable:

- Accession codes, unique identifiers, or web links for publicly available datasets
- A list of figures that have associated raw data
- A description of any restrictions on data availability

As stated in the Data availability section of the published article: "Data and documentation for all 258 cases in the mapping participation comparative case analysis can be openly accessed at: https://doi.org/10.6084/m9.figshare.13850975. Data and material that support the findings of the DDM study are available from the corresponding author upon request after two years from publication of this article."

Field-specific reporting

Please select the one below that is the best fit for your research. If you are not sure, read the appropriate sections before making your selection.

☐ Life sciences ☒ Behavioural & social sciences ☐ Ecological, evolutionary & environmental sciences

For a reference copy of the document with all sections, see nature.com/documents/nr-reporting-summary-flat.pdf

Behavioural & social sciences study design

All studies must disclose on these points even when the disclosure is negative.

Study description

The study type was mixed-method in two parts. The first part employed a comparative case mapping method which linked a form of systematic review methodology with qualitative comparative case study analysis. The second part integrated a form of quantitative multicriteria analysis with qualitative deliberative workshops as key elements of an established method called Deliberative Mapping.

Research sample

The sample for the comparative case mapping part was 258 cases of public participation and engagement with UK energy system transitions occurring between 2010-2015. The source of the sample was derived through systematic searches of the databases of Web of Science, Scopus, Google Scholar and Google. The rationale for the sample is that it reflects the diverse and varied forms of participation occurring across the UK energy system, rather than focusing on any one form of public engagement as is most often the case in existing studies.

The sample for the Distributed Deliberative Mapping (DDM) involved 5 groups, comprising one group of specialists and four groups of citizens. Citizen groups were selected to be reflective of the four broad categories of public participation with energy identified in the comparative case mapping, namely: deliberative citizens, consumer citizens, activist citizens, and grassroots innovator citizens. The sampling of specialist and deliberative citizen groups followed the established procedures of expert elicitation and deliberative processes used in conventional Deliberative Mapping. The specialist group (n=7) involved senior energy specialists selected to reflect the main UK sectors of government, business, NGOs and academia. The deliberative citizen group sample involved selecting a quota of lay citizens reflective of key socio-demographic characteristics of the population of Norfolk, UK (n=9). This lay citizen group was drawn from responses to an online survey administered by the research team through the Norfolk County Council 'Your Voice' citizens panel (n=118), which took account of age, gender and socioeconomic status variables as well as world issues of most concern (such as climate change, world population, poverty or an economic downturn), relationships with energy (such as smart meters, domestic renewables or paying bills) and preferred approach to an energy transition (expert, market or collectively led). The enrolment of the three additional groups was quite different, involving the identification and invitation of already existing groups in society based on their pre-existing models of participation, namely a UK environmental activist group which formed in opposition to a multinational oil and gas company (n=6); a grassroots Mutual Society seeking to innovate and improve energy efficiency and reduce the carbon footprint of its community in Oxfordshire, UK (n=11); and members of a smart energy control technology trial in Wiltshire, UK (n=8).

Sampling strategy

The sampling strategy for the comparative case mapping part involved using search terms to identify relevant papers and other materials on Web of Science, Scopus, Google Scholar and Google. Searches were based on the structure of 'UK' + 'energy' + 'public' + 'participation'. However, as the sample mainly consisted of interpretive qualitative case studies it was necessary to use a large number of different synonyms in the searches to pick up on different forms of and approaches to public participation and engagement. For example, synonyms for energy included 'electricity', 'heat', 'transport' and 'biofuels'; synonyms for public included 'user', 'stakeholder', 'consumer' and 'citizen'; synonyms for participation included 'engagement', 'dialogue', 'survey' and 'protest'; and synonyms were used for different parts of the UK. The synonyms used were systematically identified through an initial reading of relevant academic literature on energy participation and advice from the project's expert advisory panel during the scoping phase of this process. The criteria for inclusion of cases into the sample were that there needed to be enough documented evidence for the case to be analysed according to the key categories of participation: namely, the who (i.e. participants), the how (i.e. model) and the what (i.e. object) of energy participation. The Web of Science and Scopus searches were exhaustive. Due to the much higher number of results produced by Google Scholar and Google, for these searches the first four pages of results were reviewed and the researcher only proceeded further if relevant cases were still found after four pages. So, data saturation was a criterion used to decide whether no further sampling was needed.

The sampling procedures for each of the five groups in the Distributed Deliberative Mapping process are described above (under Research sample). The number of participants in each group was in line with that expected in qualitative and deliberative group research processes. More broadly, the sampling of the five groups was designed to address the theoretical basis and a key question of the research about whether the specific model and practice of participation shapes outcomes. The sample of five groups was therefore selected to be reflective of the diverse models and practices of public engagement with energy in the UK as identified in the first comparative case mapping part, rather than to be representative of the UK population as a whole.

Data collection

The data collection procedure in the comparative case mapping part of the study involved searching the above-mentioned search engines using a computer and collating documentary evidence. In the Distributed Deliberative Mapping (DDM) part of the study, data was collected using audio recordings (which were fully transcribed), pen and paper note taking, writing on post-it notes and flip chart sheets, and (for the specialist workshop) recording appraisals in Multicriteria Mapping (MCM) software (see https://www.multicriteriamapping.com) on a laptop computer. More than one member of the research team was present at every DDM group process, with one researcher always playing the role of observer and ethnographer of proceedings. The research team sought to be openly reflexive in attending to how the framing and make up of each DDM group shaped the process and outcomes.

Timing

The comparative case mapping sampled cases of public participation and engagement in UK energy system transitions between 2010 and 2015. The Distributed Deliberative Mapping data collection occurred in the first half of 2017 (January-July).

Data exclusions	No data were excluded from the analysis.
Non-participation	No participants dropped out or declined participation.
Randomization	See 'Research sample' and 'Sampling strategy' (above) for details of the qualitative sampling procedures by which participants were allocated to the specialist and deliberative citizen groups undertaken in the Distributed Deliberative Mapping part of the study. Participants in the consumer, activist and grassroots innovator groups were part of already existing groups.

Reporting for specific materials, systems and methods

We require information from authors about some types of materials, experimental systems and methods used in many studies. Here, indicate whether each material, system or method listed is relevant to your study. If you are not sure if a list item applies to your research, read the appropriate section before selecting a response.

Materials & experimental systems

n/a	Involved in the study	
☒	☐	Antibodies
☒	☐	Eukaryotic cell lines
☒	☐	Palaeontology
☒	☐	Animals and other organisms
☐	☒	Human research participants
☒	☐	Clinical data

Methods

n/a	Involved in the study	
☒	☐	ChIP-seq
☒	☐	Flow cytometry
☒	☐	MRI-based neuroimaging

Human research participants

Policy information about studies involving human research participants

Population characteristics	See above.
Recruitment	See above.
Ethics oversight	The research presented in the article was granted ethical approval by the General Research Ethics Committee (G-REC) of the University of East Anglia.

Note that full information on the approval of the study protocol must also be provided in the manuscript.