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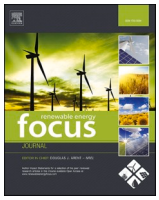

Research Paper

How do environmental values and attributes influence coastal community acceptance of tidal energy? Evidence from the Bristol Channel, UK

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ABSTRACT

Early consideration of potential societal issues, including public acceptance, is important for the effective implementation of energy policies and technologies. Conversely, lack of public acceptance can act as a barrier to their uptake, and deployment of renewable technologies has frequently been marked by public opposition at the local level. Levels of support for renewable energy are currently high, although expressions of public support do not always translate into approval for local developments, and there is significant variability in acceptance depending on a wide range of attributes. This paper provides novel insights into potential contributing factors to public acceptance of tidal energy amongst residents of coastal communities along a major inlet in the UK with high potential for tidal energy development. Adopting a largely qualitative empirical approach, nineteen participants from three coastal towns took part in photo-elicitation interviews that utilised self-taken photographs to drive discussions around local environmental (marine and coastal) attributes of importance and how these might influence participants' attitudes toward tidal energy. Selected data from a previous related energy survey provided a mixed-methods lens to reinforce specific issues raised by participants. Key findings on participants' perceptions of tidal energy included overall general positivity toward this technology, as well as recognition of its significance for sustainable energy. A range of trade-offs between issues of personal importance and the wider significance of tidal energy were also apparent. The perceived impacts of developments on environmental attributes of greatest importance to participants were thematically analysed revealing particular concerns regarding local environmental impacts and impacts on wildlife. Presented as key influencing issues on participant's perceptions of tidal energy developments, this new qualitative data improves our understanding of the issues that can lead to acceptance or rejection of proposals and are thus of relevance to a range of users, including decision-makers, consultants and developers.

1. Introduction

There is currently increasing global demand for energy. To meet this demand, while minimising contributions to climate change, air pollution and energy security issues, efficient alternatives to fossil fuel energy generation are needed [1]. Production of renewable energy is consequently also increasing globally, presenting a competitive delivery mechanism for global energy decarbonisation [2–4].

In 2019, the UK became the first major economy to adopt a legally binding obligation to reach net zero greenhouse gas emissions by 2050 [5]. Among the key decarbonisation priorities in pursuit of this target was a commitment to increase investment in renewable energy [6,7].

Tidal energy has significant potential to contribute toward decarbonisation ambitions as a result of being a renewable source, and being both reliable and predictable [8,9]. Estimates suggest that 11% of the UK's electricity demand could be delivered from tidal stream power, generating 11.5GW of installed capacity [10]. Although progress toward deployment to date has been comparatively minimal (<11 MW in 2023), largely for political and technical reasons, the UK Government recently announced a dedicated tidal stream allocation under its Contracts for Difference scheme [11], while the British Energy Security Strategy [7] committed to 'aggressively explore [other] renewable opportunities

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afforded by our geography and geology, including tidal and geothermal'. There have also been an increasing number of tidal demonstration projects in the UK and neighbouring countries to test and evidence technical advancements, job creation opportunities and ability to lower energy bills [12].

The current level of support for tidal energy among the UK public is 83%, on a par with offshore wind and higher than onshore wind [13]. Eighty-two percent believe that renewable energy developments should provide direct benefits to the communities in which they are located [13]. However, levels of general public support towards renewable energy often differ from support of specific project proposals. This can reinforce charges of 'NIMBY'ism, when in fact public attitudes are driven by more nuanced factors connected to place attachment [14].

With public acceptance being the fourth 'problem' for energy planners, in addition to sustainability, reliability and competitiveness [15], there is increasing interest in human focussed marine renewable energy research [16–18], including social, cultural, economic, health, and governance considerations [16]. Bennet [16] indicates that the current narrowness of the evidence base poses risks to ethical and appropriate actions, and to management decision-making.

Public perception studies are playing an increasingly important role in understanding community benefits, attitudes and behaviours associated with the deployment of marine renewable energy [19–22], and tidal energy specifically [23,24]. While some studies have included, to some extent, an exploration of how perceived environmental impacts resulting from energy developments affect attitudes (for example, [23,25]), few have yet attempted to make a direct connection between environmental attributes of explicit importance to members of the public and their perceptions of tidal energy. As tidal energy deployment expands it will become increasingly important to *understand* public opinion.

To address this evidence gap this research focuses on the questions: 1/ What are coastal resident's perceptions of tidal energy (developments)? and 2/ How are these perceptions influenced by marine and coastal environmental attributes that are seen as important by residents?

These questions fit within a theoretical focus on agency in defining individual beliefs, attitudes and preferences in energy use [26], while expecting some worldview influence depending on the extent of public awareness of tidal energy. The main objectives of the study are i/ to examine the factors that most significantly influence acceptance or opposition to local tidal energy developments, and ii/ through novel application of a photo-elicitation approach within a marine renewable context, to generate qualitative data, integrated with quantitative data from an earlier related energy survey providing a mixed-methods element to the research design, to reveal *and* understand perceptions toward tidal energy and the key influences on these perceptions.

2. Methods

2.1. Ethics

The methodology and objectives of this project were approved by the University of Plymouth via the Faculty of Health Committee (reference number 16/17-722).

2.2. Case study sites and Participants

Hooper et al. [24] conducted a survey in early 2018 as a related component of a broader research project (Addressing Valuation of Energy and Nature Together programme (ADVENT, NE/M019640/1)). This involved 960 residents in three case study sites along the southern coast of the Bristol Channel in south-west UK – the areas of Taw Torridge, Minehead and Weston-Super-Mare. The Hooper et al. [24] survey examined the factors that affect the likelihood that people will oppose local tidal energy developments and explored the potential for mapping community types based on their perceptions of tidal energy developments. These case study sites were selected as this area has great potential for tidal energy and has been proposed as a suitable location for a tidal power station since the mid 19th century [27]. Three sites were selected to provide spatial and demographic distinctiveness and, because populations do not always respond uniformly to environmental and social change, it is important to understand how and why people are more sensitive to certain changes and risks over others [28].

The Hooper et al. [24] survey was used to recruit participants for this subsequent photo elicitation study to generate more in-depth qualitative data to support their responses to that survey. At the end of the questionnaire, each participant was asked if they would be interested in participating in the qualitative study. No volunteers were rejected, although not all subsequently chose to proceed to participation. Fifteen people finally committed to the study. These participants were therefore self-selected. A further four participants were recruited directly from the local sea angling and boat skipper communities from the same case study sites, to take part in the photo elicitation study *only*, offering a focused perspective from those making more direct use of the marine environment. Therefore, nineteen people participated in total.

2.3. Materials and process

Mode of participant engagement: Photo-elicitation refers to the process of taking photographs and discussing/analysing these during a follow-up interview [29]. Photo-elicitation offers advantages over traditional interview formats by encouraging a more collaborative and engaging relationship between interviewer and interviewee, building rapport and trust between the parties, lessening researcher directivity, empowering self-expression, and evoking elements of human consciousness such as feelings and memories [29–31]. Alongside these strengths, researchers need to accept that the direction of travel of conversations within interviews may be more unpredictable. The use of photographs in coastal research has received growing interest with, as was the intention with this study, images contributing to understanding and engagement with coastal issues [32].

Guidance for taking photographs: Participants were emailed a project overview, guidance on taking photographs, and a consent form. The guidance was intentionally non-prescriptive to encourage participant interpretation of the brief. They were asked to 'capture images that reflected the importance of the local coastal and marine environment to them'. Participants were free to take as many photos as they wanted but were asked to subsequently select 10 images that best reflected issues/attributes of most importance to them. These selected images provided the focus for the follow-up elicitation interviews. All participants opted to use their own cameras or smart phones for the activity.

Photo elicitation interviews: Semi-structured interviews were held locally between June and October 2018 in public locations. Questions clustered around two elements – i/ what are the participants' perceptions of tidal energy developments and ii/ how are these perceptions influenced by the importance attached by participants to particular values or attributes of the local marine and coastal environment? At the start of the interviews, participants were asked to present their photographs, and for each image to talk about the subject matter and how the images represented matters of importance to them. Once all the images had been discussed, participants were asked about their perceptions of tidal energy, then asked if and how they felt tidal energy developments might impact on the matters of importance presented by their photos. Such an approach provided an opportunity for deeper exploration of the reasoning processes that individuals use to select, commensurate and prioritize the disparate risk and reward factors they attach to tidal and wave energy [33].

Survey responses: Participants were asked if they would consent to the extraction of their responses to the earlier energy survey to enable a mixed methods analysis of some of the issues being explored. Combining closed survey responses with qualitative data from the interviews

provided breadth and depth to the underlying connections between issues of importance and perceptions of tidal energy developments. All participants that completed the survey complied. The extracted survey data is presented as Appendix C in the supplementary material accompanying this article.

2.4. Data analysis

2.4.1. Qualitative data

The photo elicitation interviews were recorded, transcribed and imported into NVivo qualitative data analysis software for thematic coding. A broad *a priori* framework was created, based around the two elements listed in section 2.3, within which inductively generated themes were coded from interview content. The interviews were also inductively coded for matters of importance of the local coastal and marine environment to the participants.

2.4.2. Quantitative/mixed methods data

Responses given by the 15 photo elicitation participants that took part in the Hooper et al. [24] survey were extracted from the survey dataset and redefined into categorical data as person attributes within NVivo using the software's Cases and Classification functions. Matrix coding was then used to link the coded qualitative themes with the person attributes, allowing mixed methods analysis.

The data imported from the survey and used to generate person attributes included demographic information and responses that were particularly relevant to our research questions i.e. those which explored views on different aspects of tidal energy, the importance of seeing an increasing use of tidal power in the UK, level of support/opposition for local tidal development, and the level of awareness about tidal energy. These attributes were mapped against the three most highly referenced themes to determine if underlying patterns could be identified to explain those perceptions.

One question from the survey used a Likert scale to measure participant's level of importance they attached to five scale items covering related aspects of tidal energy in the UK. For convenience, the Likert scale responses were retained for the current study, but combined to create a new composite variable to provide an overall perception of the importance of tidal energy. The internal items were validated for internal consistency by calculating Cronbach's Alpha, a reliability coefficient particularly used for questionnaires using a Likert scale, indicating how well the questionnaire items measured level of importance.

An output from the Hooper et al. [24] survey was an assessment of relative importance participants attached to different attributes associated with tidal energy development using the Analytic Hierarchy Process (AHP) [24]. The four characteristics compared in the AHP were: local environmental impact, local job creation, cost of energy, and reliability. For the original survey, calculation of the attribute weights from the AHP was carried out using an eigenvalue calculation tool within R. The individual attribute weights were aggregated for each sample using the geometric mean to provide consistency with the accepted truisms of AHP. Scores from this exercise were extracted and analysed to allow an assessment of the preferences of multiple individuals [23], in this case the photo elicitation sample group, as compared to the whole survey population. The individual scores were also re-coded into the NVivo classification to allow cross-analysis with related coded themes from the interviews, and hence providing further insight into the participant's environmental attitudes.

3. Results

The sample was geographically balanced with six participants from Taw Torridge, six from Minehead and seven from Weston-super-Mare. The sample was also reasonably balanced across both the age and gender groups, however no under-35's participated in this study; hence it is acknowledged that this age group is not represented in this research.

3.1. Qualitative Data from photo elicitation participants (n=19)

3.1.1. Perceptions of tidal energy developments

Fig. 1 shows a concept model of the themes representing participant perceptions of tidal energy that emerged from the elicitation interviews for the whole sample. The darker shaded spheres reflect the three primary (most highly referenced) themes, which are discussed in the following sub-sections. The details for the secondary themes shown in the figure are provided as Appendix A in the supplementary material accompanying this article.

3.1.1.1. General positivity toward tidal energy (13 participants, 14 references). Although some of the other themes do include positive comments about tidal energy, they are implied from the discussion of a specific issue related to the theme, whereas 13 participants explicitly stated their positivity toward tidal energy in a more generalised manner:

> I am in favour of renewable energy sources, we have got solar panels on the house at home. I would imagine it is, I don't know a lot about it, but it is a clean energy source, um and obviously fossil fuels are dwindling so you know we do need to diversify and come up with new solutions if we want continue the lifestyle we have at the moment. *Weston-super-Mare resident*

3.1.1.2. Tidal energy as a sustainable energy source (13 participants, 20 references). Within this theme six participants (6 references) made general statements about tidal being a sustainable form of energy, while three participants (3 references) expressed concern that this energy source was not currently financially supported by government and that investment similar to the solar industry was needed.

The dominant issue (11 references) was the notable local understanding of the power and constancy of the tide, and the size of the tidal range (proudly recognised as the second largest in the world). This understanding led participants to believe that tidal provided huge potential as a sustainable energy source, and even compared favourably to wind:

> So I just believe that the amount of energy needed to get your windfarm up and running, it must take years before you actually pay that back, whereas turbines don't strike me, because it is more known technology, we have known turbines for donkey's years, we just need to work out a way of getting them under the water I think, so surely that must be a better use of resources than starting windfarms from scratch, I think. *Taw Torridge resident*
>
> I wish the UK would harness tidal power, it just seems a no-brainer, I just cannot understand why because you have got the guaranteed you know twice a day sort of you know harnessing of free electric, which you can sort of say five hundred years in advance you can see exactly when that tide will be in and you can calculate it, but why has nothing been done about that? *Weston-super-Mare resident*

Three participants discussed the need for cleaner alternatives to fossil fuel. They felt that if increased tidal energy was combined with wind, solar and a little nuclear, then this would produce a long term, predictable source of energy for this part of the UK.

3.1.1.3. Trade-offs (13 participants, 25 references). Participants often articulated their perceptions of tidal energy through a referencing frame in which they discussed trade-offs with other issues of importance or concern to them. A range of trade-offs were identified where two or more conflicting issues influenced the participants' internal considerations of what features of tidal energy developments (or sometimes wider sustainable energy sources) had the most significant impact on their perceptions.

Eight of the 13 participants within this theme indicated that the local environment (including local wildlife, access to landscapes for recreation, and views of the landscapes) was the primary consideration against

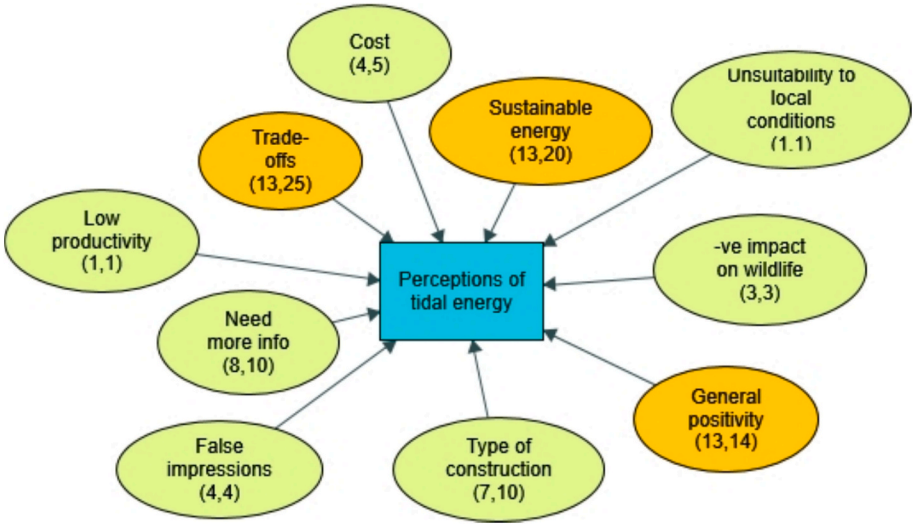

Fig. 1. Concept model of the themes representing participant perceptions of tidal energy (first figure in brackets = no. of participants contributing to the theme; second figure = no. of references made to the theme).

other factors:

> I am very keen on having energy derived from water…as long as any schemes didn't actually ruin the coast, I would be all for them, because I think we have to have a bit of give and take on things like this…Sooner or later we have got to sort the energy problem out. *Taw Torridge resident*
>
> If it was to be under the water and built properly so it doesn't affect the wildlife that lives there, I know there will be some impact, you are not going to do it without [that], but, yeah, why not? *Minehead resident*
>
> I know it can create jobs, I understand that but sometimes you have to look at the bigger [environmental] picture. *Taw Torridge resident*

Six participants emphasised the certainty of tides for providing capability for energy conversion. This reliability was viewed favourably against environmental impact, particularly where such impact could be minimised:

> …you can get energy from the tide, but I think you pay the consequences in lots of other ways. But I think the small-scale ones, probably yes, you know if you get a small-scale lagoon you can generate a certain amount of power from that without it having an undue effect [on the environment] I would have thought. *Minehead resident*

Even when reliability was explicitly put forward by participants as a key factor to consider, there were still some caveats attached around environmental impact:

> I strongly agree that [tidal energy] is a good way to go. We have got to do something for our electric long term, there is obviously more and more people growing, everything you can see with the houses being built, we are expanding, we are using more energy, we need to do something that is obviously green, and the tide is there, I mean all that power, you know the power of the sea, and it is going to waste, so I am all for it. As long as they do it safely to not impact, not make the coastline damage worse or the marine life, as long as it done safely then I am all for it. *Minehead resident*

Only two participants highlighted job creation as a priority interest, and these were in relation to opportunities created by the nearby nuclear power plant at Hinkley Point and at the Butlin's seaside resort.

The sample included several participants that had work or hobby interests in the channel's fish population, thus it is not surprising that at least one view considered increasing and sustaining fish stocks as an important factor, even when it comes at the expense of the aesthetic quality of natural panoramas. Giving the example of windfarms off the county of Kent's shore, one sea angler pointed out evidence that fish stocks had increased around the water surrounding the turbines, suggesting that the same might be true of tidal constructions.

One final trade-off acknowledged the importance of tourism in the case study sites. One participant questioned whether marine devices would attract curious visitors, or whether they would be detrimental to tourism due to possible unsightliness. A further participant would reluctantly accept spoiled views from tidal developments in favour of the more unsightly alternative of nuclear power plants.

3.1.2. Impacts of tidal energy development on participants' self-identified matters of importance related to coastal living

Fig. 2 shows a concept model of the themes representing participant perceptions of the impacts that tidal energy developments might have on their self-selected issues of importance of their local coastal or marine environments. The darker shaded spheres reflect the two primary (most highly referenced) themes, which are discussed in the following sub-

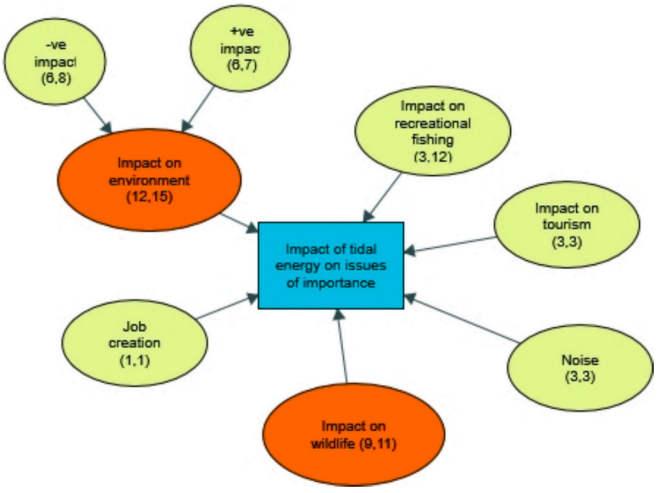

Fig. 2. Concept model of the themes representing participant perceptions of the impact of tidal energy developments on their identified matters of importance of their local coastal/marine environment (first figure in brackets = no. of participants contributing to the theme; second figure = no. of references made to the theme)

sections. The details for the secondary themes shown in the figure are provided as Appendix B in the supplementary material accompanying this article.

3.1.2.1. Impact on local environment (12 participants, 15 references). Of the twelve participants that provided explicit reasons why they believed that tidal energy developments *would* impact the local environment, half thought these impacts would be positive. One person felt that a riverine tidal barrier would preserve the current tranquillity and beauty of the coastline and estuary and encourage greater variety of recreational use. Another respondent thought that a tidal device might reduce the strength of inward water flow, thereby contributing to a reduction in coastal erosion. Some respondents had negative views of the nearby power plant and therefore felt that a tidal device would provide a cleaner alternative for current and future human generations. Another viewpoint expressed by a few interviewees was that the marine environment was either large enough to encompass a tidal construction without interfering with aesthetic quality, or indeed that it would provide visual features that might stimulate additional interest for people. A further view suggested that tidal devices would present a much more subtle presence within a marine environment than a wind turbine.

With regard to negative impacts, these included concerns over construction methods where devices are required to be fixed to the sea floor, the possibility of devices that were unsympathetically designed or constructed without properly taking the surroundings into consideration, spoiling outward facing views from the coast, silting up of the harbours, and restrictions to recreational enjoyment if sited too close to the coastline.

3.1.2.2. Impact on wildlife (9 participants, 11 references). When initially asked an open question about their perceptions of tidal energy only three participants explicitly expressed concerns that tidal developments would negatively impact on wildlife. One respondent consistently voiced her opposition to marine developments on the premise that they would destroy wildlife, although it became apparent that her views were formulated solely from her perceptions around windfarms. When participants were subsequently asked to explore their thoughts about impacts of tidal energy on the matters of importance related to coastal and marine environments that they had previously identified through their photographs and interviews, this theme emerged as the most significant, with further considerations offered by half of the interviewees.

There was general concern from four people that there might be a negative impact on marine life or at least that marine life must be a priority consideration prior to any development. Some comments considered this issue in a broader 'renewable energy' context:

> As somebody who is interested in nature and conservation, I was concerned about [wildlife] because of the effects of whether or not it would silt up the estuaries um... I think they would have to do a major study but a lot of the RSPB, the Wildfowl and Wetlands Trust were against it because it is a very important breeding ground for waders along the Severn Estuary there yeah, but also I can see the advantage of having renewable energy. *Weston-super-Mare resident*

Specific concerns were expressed around potential damage to wildlife during any construction process, and the unknown impact of turbine noise and vibration on underwater species such as migratory fish, dolphins and whales.

Two of the sea anglers felt that tidal energy developments might disrupt local salmon passages, based on their understanding that this phenomenon had been negatively impacted by the damming of a local river to build a bridge.

One participant was more concerned about any potential impact at the local marine ecosystem level rather than on particular wildlife species or groups.

3.2. Mixed-method analysis (n=15)

3.2.1. Case study site

When considering the six themes arising from the impacts of tidal energy on participants' matters of importance (see Fig. 2), Figure 3 shows how these themes vary across case study sites. The participants from the Minehead location expressed comparatively more concerns about the negative impacts on the environment, but had no views on potential impacts on noise, tourism and recreational fishing. Participants from all three sites had similar levels of concern regarding impacts on wildlife. There were 10 references from the Taw Torridge site to impacts on recreational fishing, most of which came from one participant, a keen sea angler.

3.2.2. Length of residence

When accounting for bias in the numbers of participants within each 'length of residence' group (0-10 years, 11+ years) both groups supported or strongly supported tidal developments. One participant in the 11+ years category held no opinion either way. These figures evidence over-arching support of tidal energy by the participants.

3.2.3. Importance of tidal energy in the UK

The Hooper et al. [24] survey presented five statements exploring participants' views on different aspects of the importance of tidal energy (Fig. 4). Eleven of the fifteen participants agreed or strongly agreed that tidal energy was important, the remaining 4 participants expressing no opinion on the matter.

Table 1 extracts the composite variable data above and plots these against the three most highly referenced themes from the participants' perceptions of tidal energy (Figure 1). For all of the themes a majority of participants strongly agreed or agreed that tidal energy in the UK is important. However, a greater proportion (seven of the eighteen (39%)) of contributors to the trade-offs theme had no opinion either way on the importance of tidal energy.

To determine if a positive perception of tidal energy is influenced by level of awareness, the same three themes were mapped against the attribute 'awareness of tidal energy'. Participants were divided regarding their level of awareness, with a majority of participants self-identifying as either quite well or not very well informed across the themes (Table 2). The majority of the qualitative study participants who identified the need for more information about tidal energy before they would commit to supporting it or not (s3.1.1.5, Appendix A), reported themselves in the Hooper et al [24] survey to be 'not at all' or 'not very' informed about tidal energy. Participants contributing to the themes 'generally positive about tidal energy' and 'source of sustainable energy' were slightly better informed, while 7 of the 11 participants that needed to consider trade-offs in their perceptions were either not very well or not at all informed about tidal energy.

3.2.4. Level of support or opposition to local tidal energy development

From the Hooper et al. [24] survey responses, fourteen of the fifteen participants would support or strongly support a tidal energy development in their area, while 1 person had no view either way (Table 3). When these results are plotted against the three most highly referenced themes within perceptions of tidal energy (Figure 1), a similar pattern of support is shown across the themes, although a slightly higher number of participants that contributed to the trade-offs theme strongly supported or supported local development compared to general positivity and tidal as a source of sustainable energy (Table 3).

3.2.5. Comparison of qualitative trade-offs themes to AHP survey responses

Thirteen photo elicitation participants contributed references to the theme 'trade-offs' (see s3.1.1.3), and also completed the AHP component of the Hooper et al. [24] survey, allowing a comparison of the quantitative and qualitative responses around this aspect of tidal energy perceptions. The qualitative results are largely supported by the AHP

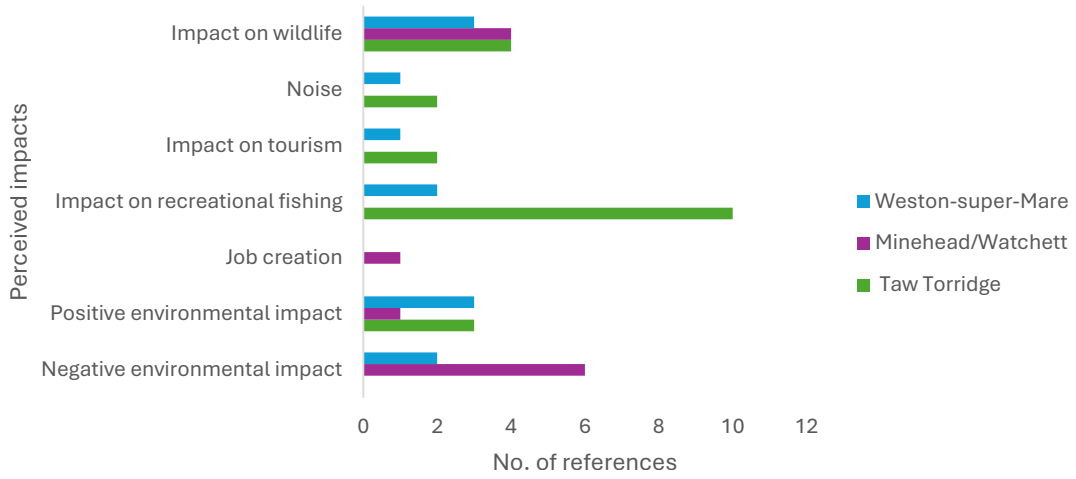

Fig. 3. Perceptions of impacts of tidal energy on participants' matters of importance, by case study site

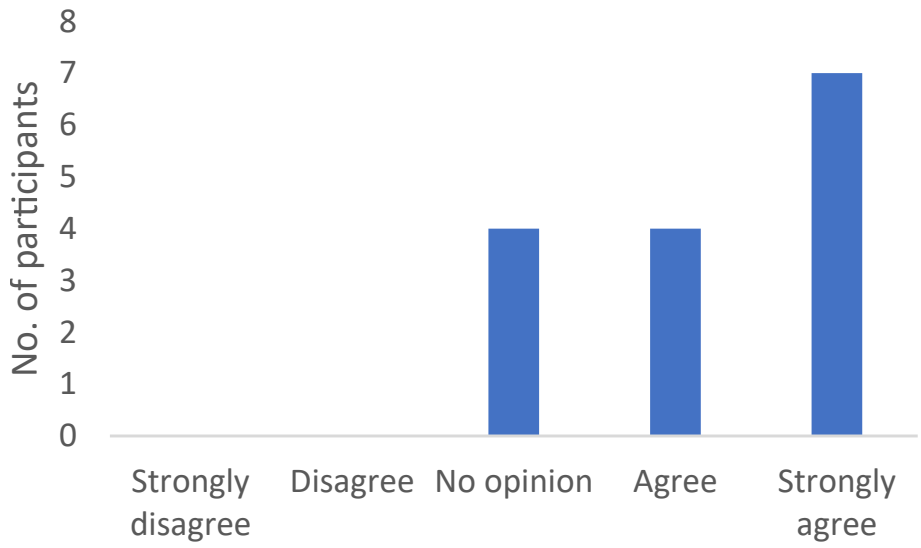

Fig. 4. Survey results (N=15) for composite variable showing participant perceptions of importance of tidal energy in the UK. Data were formed from a construct of a 5-item Likert scale (from strongly disagree to strongly agree) that consisted of 5 statements: Important that the UK continues to increase amount of electricity from renewables; Important that the UK plays a leading global role in research and development for tidal energy; The UK Government should invest more in tidal energy; The scale of engineering challenges will stop tidal energy ever really taking off; and Tidal energy will not make a significant contribution to UK electricity supply. The latter two statements were reverse coded to enable consistent scoring against the direction of positivity or negativity. Internal consistency between statements was acceptable (Cronbach's alpha 0.791).

Table 1
Relationship between the importance of an increasing use of tidal energy in the UK and the three most frequently referenced themes relating to tidal energy. Figures shown are for number of participants.

	The Importance of tidal energy in UK					
Participant Perception	**Strongly agree**	**Agree**	**No opinion**	**Disagree**	**Strongly disagree**	**Total**
Generally positive about tidal energy	8	1	2	0	0	11
Source of sustainable energy	10	1	3	0	0	14
Need for trade-offs	9	2	7	0	0	18

exercise with environment-related issues featuring strongly relative to other matters of importance to participants.

The AHP undertaken by survey participants required each person to score relative importance between four characteristics on a pairwise basis. Fig. 5 shows that across the whole survey sample (N = 960) local environmental impact (AHP aggregated weight score of 0.28) was viewed as a proportionally more important characteristic of tidal energy developments than local job creation (0.20), cost of energy (0.15) and reliability of energy production (0.18). With four characteristics being compared, the maximum weight that could be ascribed to each one is 0.75. Fig. 5 also shows that when the responses for the current study participants were extracted from the broader survey sample it is clear from the AHP mean weight scores that local environmental impact (0.54) was afforded even greater importance, relatively, than the other characteristics, compared to the wider survey respondents (AHP 0.28).

Note that while some participants of the survey did prioritise

Table 2
Relationship between level of awareness on tidal energy and the three most frequently referenced themes relating to tidal energy. Figures shown are for number of participants.

Participant Perception	Level of awareness about tidal energy				
	Very Well	Quite Well	Not Very Well	Not at all	Total
Generally positive about tidal energy	1	5	3	1	10
Source of sustainable energy	1	4	3	1	9
Need for trade-offs	1	3	5	2	11

Table 3
Relationship between level of support for local tidal development and the three most highly referenced themes relating to tidal energy. Figures shown are for number of participants.

Participant Perception	Level of support for local tidal development				
	Strongly Support	Support	No Opinion Either Way	Not Support	Total
General positivity about tidal energy	3	6	0	0	9
Source of sustainable energy	4	4	0	0	8
Need for trade-offs	4	7	1	0	12

reliability of tidal energy as a key characteristic, the importance of reliability was referenced more frequently in the qualitative study (N=6 of 13) than the survey suggested (AHP score 0.18) (Fig. 5). Not all trade-offs presented by the photo elicitation participants could be aligned against the AHP characteristics. For example, two participants were more concerned with local community economic gains (or at least, no economic loss) than sustainability. Hence, a resident might be in favour of tidal energy as long as the longer-term costs of maintenance do not end up falling on the local community.

Another example highlights a willingness to sacrifice aspects of personal significance, such as the value of aesthetic views, for the greater good i.e. sustainable energy:

> Again, at the same time I kind of think, maybe the needs of our family weighed up against the needs of generating electricity, the needs of our family come out small in comparison, so you know if they built something here and we lost it if it was for the greater good I would be happy with that. *Weston-super- Mare resident*

4. Discussion

This paper aimed to answer two questions: 1/ What are coastal resident's perceptions of tidal and wave energy (developments)? and 2/ How are these perceptions influenced by marine and coastal environmental attributes that are seen as important by residents?

A mixed-method approach was adopted, integrating qualitative data from a photo elicitation activity involving 19 coastal residents from three locations in south-west UK, and quantitative data for 15 of those residents who also completed a related energy survey [24]. Perceptions of tidal energy were harnessed from thematic analysis of elicitation interviews and exploration of extracted survey data to provide a sample-wide understanding of the critical influencing elements of participants' views on using tidal energy for electricity generation.

The environmental attributes and characteristics of tidal energy developments which influenced participants' overall perceptions of tidal energy were examined through a combination of thematic analysis of interview data and categorisation of selected survey data into participant attributes to enable cross-referencing between the qualitative and quantitative data. This then provided information that revealed *what* was important to participants and *why* it was important to them.

Research question 1: What are coastal resident's perceptions of tidal and wave energy (developments)?

Three key perceptions of tidal energy for the majority of participants were that they were generally positive about the concept, that the sustainable nature of tidal as an energy source was recognised, and that in forming their views of tidal energy there were a range of trade-offs between issues of importance associated with their local coastal environment that needed to be considered. Several other perceptions of tidal energy were raised to a lesser extent, including the need for more

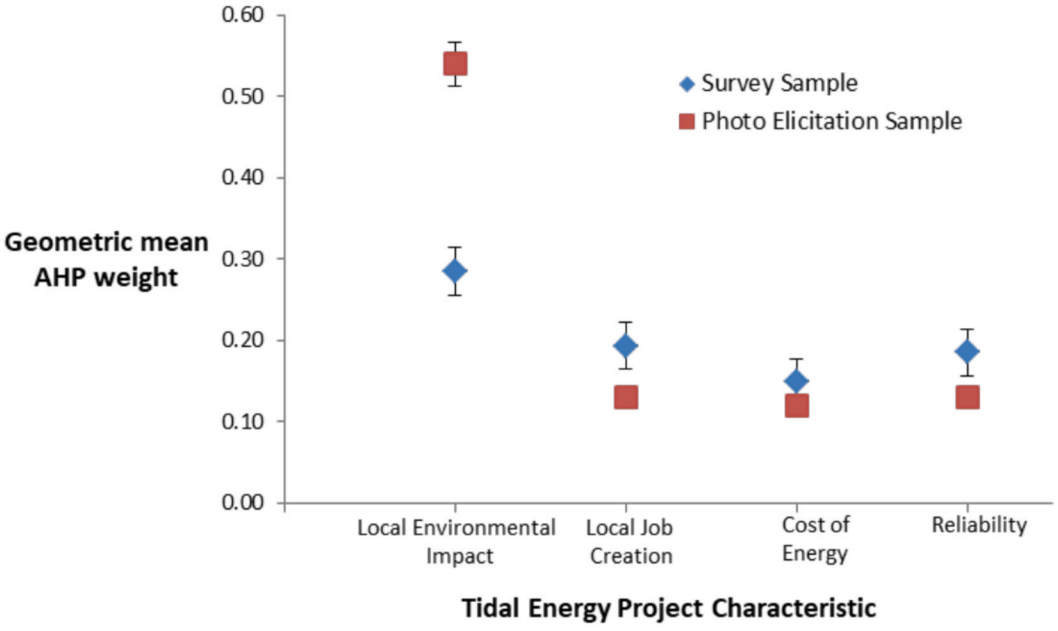

Fig. 5. Comparison of importance of different characteristics of tidal energy projects for the survey sample and photo elicitation study sub-sample (error bars indicate 95% confidence interval)

accessible information about the subject, understanding on different types of tidal/wave energy device construction, and perceived costs associated with developments.

The overall expression of support for tidal energy from this study reflects similar findings from other research [24,33–35].

The participants who expressed their positivity toward tidal energy in general terms did so without explicit reasoning behind this support. Those extolling the virtues of the reliable nature of tidal as an energy source did so mainly because of their own experience of the power and size of the Bristol Channel tidal flow and range. For some, there was genuine confusion as to why such energy potential had not been utilised to date, particularly when compared to other local energy developments which had received investment, notably the Hinkley Point Nuclear Power Station on the North Somerset coast.

Of note is that half of the study group were self-reportedly not well informed yet showed overall positivity toward tidal energy. Despite an acknowledged lack of expertise, the participants felt able to express their support, perhaps supporting conclusions from other studies that people's worries and concerns about climate change can spark enthusiasm for renewable energy sources [36].

Participants reflected on a number of issues which they needed to reconcile to determine what they really thought about tidal energy. Trade-offs around conflicts between a range of matters were revealed by the collective participants. There was close alignment between the attributes considered most important via the qualitative interviews and those prioritised during the energy survey as part of an AHP exercise. However, there was a notable additional emphasis on concern for local environmental impact demonstrated by the photo elicitation participants. This is potentially a 'social desirability' effect where interview respondents may have felt inclined to provide 'correct' answers to align more closely with the perceived interviewer organisations' environmental interests [37,38]. Another possibility is that because the photo elicitation sample was self-selected, the final group of participants may have been more pro-environmentally minded than a broader population and therefore potentially subject to the effects of self-selection bias [39].

However, the photo elicitation study presents a useful method to reveal some of the contributory factors to the AHP scores; for example, the explicit concerns expressed regarding local wildlife contributing to higher scores for the characteristic 'environmental impact'. One of the other characteristics used for the AHP was 'reliability', defined in the energy survey as 'The tides could generate electricity every day, at times and in amounts that can be reliably predicted' [24]. Because pre-defined tidal energy characteristics were not given to the photo elicitation participants there is a possible different interpretation of the term when considering participant perceptions of tidal energy. Some participants definitely reflected the definition given above in relation to the nature and power of tidal flows in the Bristol Channel, while others pointed out the high levels of sedimentation in the harbours and other parts of the channel which they linked to a need for reliable tidal infrastructure machinery, without quickly leading to maintenance costs falling on the local communities.

Because the energy survey predated the photo elicitation exercise it is possible that the former raised awareness for the latter through the engagement between surveyors and surveyees, which may have also subsequently activated independent fact-finding leading to an enhanced self-awareness declaration come the interviews. This outcome was made explicit by one individual but could equally have applied to others.

Despite the high number of participants that expressed concern about local environmental impact of tidal energy, none suggested they would oppose a local tidal energy development.

Research question 2: How are these perceptions influenced by marine and coastal environmental attributes that are seen as important by residents?

The attributes of the coastal environments considered of most value to the participants who live, work and play in them, are revealed through their concerns over several broad perceived impacts arising from tidal energy developments. Of particular concern to many participants was the potential impact on local environment quality, both positive and negative. Several participants saw environmental benefits from the addition of local tidal developments, including the creation and protection of coastal areas of tranquillity and beauty, the reduction of coastal erosion, and the presence of cleaner long-term energy provision. While there were some claims that the likely scale of tidal developments wouldn't seriously impact on the aesthetic quality of the marine environment, there were also opposing concerns that outward-facing views might be spoilt by unsympathetic construction designs. Such perceptions are important in that people are more likely to support local developments if they do not negatively impact on local aesthetic attributes [15].

Participants that particularly valued wildlife were worried about effects of the construction process as well as methods used to anchor devices to the channel floor, while those involved in the local sea angling industry and those interested in birds, felt that the already-problematic silting of harbours might be worsened. The impact of noise and vibration from construction and operation of tidal devices on marine species behaviour, particularly migration patterns, was considered an unknown, and therefore a possible threat.

Other relevant impacts of tidal and wave developments perceived by participants included possible influences on coastal tourism and recreational fishing, but, again, these threats attracted mixed reactions. For example, the 'marine participants' recognised the potential benefit of tidal devices for providing new fish and shellfish habitats, while at the same time acknowledging that such devices might limit access to seabed features and associated ecotourism experiences.

Many of the concerns around impacts from tidal energy developments revealed in this study are supported elsewhere, for example, Wiersma [40] (quietness, wildlife, recreational opportunities, tides, natural beauty), Bailey et al. [33] (risks to wildlife, visual quality, environmental quality and tourism, and benefits to job creation), Devine-Wright [14] and Hooper [23] (impacts on local wildlife). While most of the marine environmental attributes identified as important by participants of this study could align to Roddis et al.'s [41] 'material arguments' that form part of the acceptance variables which contribute to their community acceptance framework for offshore wind and solar, this study arguably extends those arguments through consideration of more dynamic qualitative and intimate impacts that influence perceptions; for example, impacts on recreational activities and other personal engagements with the marine and coastal environment.

The majority of participants in this study agreed that it was important that the UK increases its use of tidal power to supply the nation's energy, influenced by their general positive views of tidal energy and their appreciation of the sustainable nature of this supply mode. Support for local energy tidal developments was strong regardless of the length of residence in the area potentially impacted by development. Public acceptability has been shown to vary across development lifecycle stages with support declining once a project transitions from concept to the water, and increasing once a grid-connected pilot stage is reached [42]. Community consultations and policy development may result in higher public acceptance, therefore, if incentives for pilot phases with grid-connection are included.

The self-identified level of awareness of tidal energy revealed by the participant sample reflected Hooper's [23] study, and those feeling better informed were explicitly positive about tidal energy and recognised the sustainable nature of the tides, while a majority of participants that highlighted trade-offs were not well informed about tidal energy. This suggests that lower awareness could feed greater uncertainty about participants' own positions on tidal energy, and also that the priorities afforded to various characteristics of tidal developments and environmental attributes may be fluid and change as awareness is raised. The need for more information about developments, including details or evidence of potential impacts on issues of importance to the participants, was identified as an important requirement that would undoubtedly affect public opinion and decisions to support developments

or not. Devine Wright [14] advised of the need to have effective communication and public engagement in order to increase local support, while Bailey et al. [33] warned that where communities have limited prior awareness of the impacts of new technologies and information is subsequently shared in a piecemeal manner, then inconsistent patterns of public opinion are a likely outcome.

Extracted survey results revealed that the sample participants would be supportive of a tidal energy development if it were proposed for their area, with not one person opposed to the idea. Of note is that of the top three themed perceptions of tidal energy, participants that highlighted trade-offs were the most likely to support local tidal developments, suggesting that whatever those issues of internal conflict and consideration that people wrestle with when forming their views of tidal developments, they are not sufficient to take-away from a sense of overall support. This point suggests that where participants need to weigh-up competing issues, possibly as a result of lower awareness of tidal energy, the resultant considered view is one of strengthened support.

Devine-Wright [43] suggested that perceptions of technology projects are likely to vary by location, even when fairly equidistant from the development, caused by different conceptions of the 'symbolic fit' between project and place. In this study, there was certainly some variation across case study sites on which coastal attributes participants afforded most importance, but for perceived impacts of tidal energy developments *on* these attributes, the most notable variation was that participants from the Minehead area raised more negative environmental impacts than the other two locations, and that participants noting impacts on recreational fishing were nearly all from the Taw Torridge site and, unsurprisingly, most were involved in the sea angling industry. This example illustrates de Groot & Bailey's [44] conclusion that distinctive local circumstances and place-based values are highly influential on communities' level of support for marine energy developments.

Underpinning this study was an approach to understanding public perception that sought views that were embedded in the local-ness of the case study sites, specifically connecting perceptions of tidal energy and conceptual/potential tidal developments to matters of local importance framed around the coastal and marine environment. This compares to other approaches that have taken a broader tact when eliciting importance of issues that might impact on perceptions and opinions of marine renewable energy. For example, Westerberg et al.'s [15] analysis framework on tourist's opinions of offshore windfarms considered global topics such as climate change and alternative energy producing methods (as variables), as well as project specific factors such as reliability, costs and environmental impacts. They forewarned that where researchers or consultants may think they are eliciting preferences for objective characteristics of a landscape or project, those preferences may actually be intrinsically shaped by wider political, technical, economic or ecological implications of the type or nature of development. Such understanding may better explain the effect of individual or community opposition or acceptance. Immediate familiarity with broader global issues may also heavily influence community acceptance of renewable energy projects at a local level. Interviews for the current study took place in 2018, at a time when concern for climate change was increasing [35], therefore potentially elevating support for a more 'environmentally-friendly' form of energy production.

This study identified a wide range of 'matters of importance' to participants in respect to living, working or playing in their local marine and coastal environment. It is recognised that these environments afford the functions that are important and meaningful to individuals [45] and, as a result, that people can develop emotional bonds with places, particularly with natural locations that individuals consider to be their favourite place. In this study, participant photographs depicted such places in connection with childhood vacations, family activities, and daily rituals that created positive memories [17]. Such place attachment or 'place distinctiveness' [14,40] can potentially play an important role in forming attitudes and behaviours toward renewable energy, particularly where developments might be seen to have various impacts on local attributes of importance. van Putten et al. [46] recognised that 'sense of place' was an important human dimension to incorporate within decision-making processes for marine resource management and could influence the success of management interventions. They purported that a stronger sense of place will lead to pro-environmental attitudes and behaviours.

The AHP evaluation of trade-offs between different characteristics of tidal energy development projects that was used in the earlier energy survey indicated that impact on the local environment was by far the primary factor motivating the photo elicitation study participants' perceptions of tidal schemes [24]. In slight contrast to Devine-Wright's [14] conclusions, this study suggests that the requirement for developers and decision-makers to present a strong economic case for tidal energy proposals is certainly less obvious than other factors, particularly local environmental impact. The relative lack of showing of job creation as a driving impact on perceptions of tidal energy also counters Ponce-Oliver et al.'s [47] finding that this attribute had a significant positive effect on social acceptance.

The findings of this study suggest that it is important that decision-makers and developers go beyond simply courting nods of social acceptance and take the time and effort to understand what it is that people value about places that might be affected by proposed developments, perhaps usefully determined via social impact assessments [48]. Being aware of the attachments to place and, hence, potential sensitivities to changes will highlight risks that should be addressed. As Kazimierczuk et al. [49] point out in their marine renewable energy case study of coastal communities in Alaska/Canada, environmental or place-based values are rarely acknowledged in community consultations, potentially leading to conflicting priorities within decision-making processes. The participants of this study revealed a range of different places and characteristics that they deemed important and which would likely determine how they perceive changes and impacts arising from developments. A development that resonates with these identified important values in their local environment; for example, a tidal energy device in a channel with powerful currents producing renewable, reliable energy with less impact on environmental quality than alternative energy sources, is likely to receive greater acceptance of proposed changes.

Moving to a broader scale than energy this work has potential to inform wider decision making. For example Marine Plans, such as the Marine Management Organisation's (MMO) South-West UK Marine Plan (which covers the study area) demands adherence to the mitigation hierarchy – avoid, minimise, mitigate, and where mitigation is not possible, ensure that public benefits of the proposal outweigh significant adverse impacts to the seascapes and landscapes of an area. The SW Plan acknowledges that there is an existing but increasing emphasis on social values in planning for and making decisions on activities in the marine area and requires that proposals should demonstrate that they have considered how highly the seascapes and landscapes of an area are valued [50]. A marine spatial planning framework utilising a decision support system that incorporated stakeholder and public perception data, on a spatial basis, identifying areas and characteristics of most value, akin to that obtained from this study, could help form negotiations to minimise conflict [17] and go some way toward satisfying the requirements of the marine planning process.

The authors acknowledge that this study is based on a modest sample size and that the case study locations, although distinct, are situated within a region of shared characteristics on the southern coastline of the Bristol Channel. Further research could usefully extend sample size and broaden study sites, nationally and internationally, to test the consistency of values coastal communities attach to environments potentially subjected to the threats or opportunities afforded by tidal energy developments. The thematic application of this study's participant perceptions might usefully be extended to produce, for example, mental models of benefit perceptions (both from the public *and* energy experts)

[51], so that information on risks and benefits of tidal energy developments can be communicated, allowing for more considered opinions to be formed, and serve as a strong predictor of public support for this form of energy technology. Furthermore, the application of quantitative methods such as multi-criteria decision analysis (MCDA) could present a useful validation of the importance of a range of criteria or indicators. This might effectively highlight trade-offs and interconnectedness between different energy, economic, technical, and environmental factors, even more clearly than the present study.

5. Conclusions

It is important for energy sector and planning decision-makers to understand the issues which concern communities, and the benefits potentially impacted communities would want realised, to gain their support and minimise opposition to proposed renewable developments. Failure to advance this understanding may result in local conflict forcing developments elsewhere, and into potentially less effective, efficient and societally acceptable locations. There is national level support for renewables but to enable smooth transition at a local and regional level a comprehensive understanding of numerous variables is required.

The way that coastal communities value their local marine environments are often measured through methods that monetarize those values. Recent research suggests that by measuring these values in monetary terms, the nuances and understandings about the importance of ecosystems for human well-being can be lost [52]. This paper has demonstrated that qualitative approaches, particularly methods which enable participants to at least partially drive discussions, can be particularly effective at revealing such nuances that might lead parties requiring public support for marine renewable developments closer to the issues that lie at the heart of acceptance or rejection. In this case study, acceptance would likely be dependent on a developer's and consenter's consideration of impact on the local environment and wildlife in particular, as well as on recreational fishing, tourism and from noise. More generally, addressing concerns around specific, identified, local impacts will be particularly beneficial in further increasing the acceptance of renewable energy developments.

CRediT authorship contribution statement

Andrew Edwards-Jones: Writing – review & editing, Methodology, Conceptualization, Writing – original draft, Data curation, Visualization, Formal analysis. **Caroline Hattam:** Methodology, Supervision, Data curation, Writing – review & editing, Conceptualization. **Tara Hooper:** Writing – review & editing, Conceptualization, Methodology. **Nicola J. Beaumont:** Resources, Writing – review & editing, Funding acquisition.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: [All authors reports financial support was provided by UK Energy Research Centre. If there are other authors, they 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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Appendices A-C. Supplementary data

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Data availability

Data will be made available on request.

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