Energy Research & Social Science 101 (2023) 103117

Contents lists available at ScienceDirect

Energy Research & Social Science

journal homepage: www.elsevier.com/locate/erss

Original research article

From data to strata? How design professionals "see" energy use in buildings

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ARTICLE INFO

Keywords:
Architects
Buildings
Design
Engineers
Energy use
Perceptions
Visual research methods

ABSTRACT

Improving design for efficient energy use in the built environment is a critical area for decarbonisation policy and practice. To date, this research emphasises improving tools and technology for predicting and managing energy use in buildings. No studies to date have explored how energy use is conceptualised by building design professionals. As such, this paper asks - how do architects and engineers 'see' and perceive energy use in UK Higher Education (HE) building design? Addressing this question is key to advancing how design professionals and building stakeholders can work together more effectively when designing for decarbonisation. We present visual narratives from 14 UK-based design professionals that include over 100 participant-produced photographs taken to represent their ways of 'seeing' energy use when designing HE buildings. The photo-elicitation interviews and images are analysed using Grounded Visual Pattern Analysis. The contributions of this research are twofold; first, they show how energy use is 'seen' and understood as both dehumanised graphs as well as emotion, personal values, family, and the natural world. This duality and contradiction sheds new light on the underlying tensions and competing professional/personal demands associated with the work of professionals designing for decarbonisation. Second, the paper provides new directions for the study of energy using visual research methods. Participant-led photography generates a different set of data that provides a deeper understanding of designers' conceptualisations and moves us beyond the dominant technological focus that is currently emphasised in research, policy, and practice.

1. Introduction

Use of energy in buildings has been a well examined area within multiple domains of research including the built environment [1,2], engineering, building science [3–5], sociology, anthropology, and economics [6–8]. Most studies have tended to focus on ways to reduce energy use in buildings through better predicting or managing its operation primarily by monitoring performance [5] or through study of user perceptions and perspectives [7]. A significant research effort has also continued to be placed on highlighting how building energy use could be reduced through enhancements in building performance simulation and modelling approaches [3,9,10], better monitoring how occupants use energy in buildings [11–13], earlier design interventions [5,14] or improved coordination and communication during design and construction stages [15–17].

Underlying this growing work across disciplines has been an emphasis placed on better understanding decisions made on energy use particularly at early design stages. By understanding how design decisions regarding energy use are being made, Guillemin and Morel [18] argued that important, potentially negative consequences for poor energy performance could be avoided. Architects' and engineers' design decisions on energy use have been studied through a predominantly technological lens by interrogating the data outputs or assumptions in building performance modelling tools, with most arguing that poor decisions are a result of insufficient data or information [19]. There has been a paucity of empirical work examining how architects and engineers conceptualise and visualise energy in buildings beyond engagement with simulation tools or data [20]. Though it has been well established that building design thinking and practices are highly experiential, reflective, and tacit [21], there have been no studies to date that have explored them in the context of energy.

The purpose of this paper is to examine associations architects and engineers draw on when thinking about energy use in buildings, what these conceptualisations mean and why they might be significant. By examining these research questions, architects' and engineers' (referred to throughout this paper as building design professionals) visual

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https://doi.org/10.1016/j.erss.2023.103117
Received 21 July 2022; Received in revised form 24 April 2023; Accepted 1 May 2023
Available online 17 May 2023

conceptualisations of energy in buildings and thereby early design decision making is better understood. Insights gained from this study open up a new way of understanding the underlying conceptualisations that inform design decisions regarding energy beyond the dominant technological frame. By uncovering the associations that drive design decisions with regards to energy, a new way of understanding what energy use means in the context of buildings is provided and a transformative approach to improved design for efficient energy use is made possible. The paper focuses on building design professionals working in the context of higher education (HE) buildings in the UK using participant-led photography to uncover the visual associations and thinking involved. Without such an approach to articulate these underexamined perspectives, the potential to better understand the ways building design professionals visualise energy will continue to be overlooked, missing opportunities for alternative conceptions of improved design practice in the context of energy use in building design.

2. Building design professionals and energy use conceptions

Energy has been characterised to be “doubly invisible”, given that its use is a largely abstract concept, difficult to ‘see’ and sense [22]. Though it has been well established that people's perceptions of ‘invisible’ energy use are entangled and embodied with spaces, items, and infrastructures of everyday life [23], their representations, inner precepts and visual scenes [24] are as yet not well known. In addition, though there has been a growing understanding that people's mental models – their internal representations – of energy are not based around energy consumption, but rather on visual categorising of external phenomena [25]. This categorising and the imaginaries that are embodied, have not yet been fully explored other than in the context of new or alternative futures or systems [26]. Drawing on comic-strip representations of digital technology and energy industry imaginaries in everyday life situations, Strengers et al. [27] revealed implicit conceptualisations of future visions of home energy use and life. While helpful in articulating future visioning and underlying implicit thinking in how energy use might be conceptualised in the home, there has been little or no engagement with those involved in *designing* such systems or processes.

The role of building design professionals in energy use decision making was characterised by Gram-Hanssen and Georg [28] as “profound” (p.7). The process of design is seen to have the potential to script how buildings, energy systems and technology are used. As Cole [29] noted, assumptions made in early design stages have long lasting effects on how users perceive and experience energy use through comfort, adaptability and general wellbeing within spaces. Pschetz et al. [30] described the capacity of design to solve complex and highly contextualised problems of energy distribution. Building design professionals have been viewed to have heightened intuition and ability to visualise and sense energy use as a phenomenological process within 3d contexts of home spaces, cities, infrastructure and people [31]. While their imagination and visual capacity have been drawn upon to imagine future and alternative scenarios in a sustainable planetary new nature, they have never been studied as a way of understanding ‘internal’ representations of energy. Where design professionals' interpretations of energy have been studied, this has been viewed largely through either a narrow technological perspective or through a future visioning and social imaginaries lens [32–35].

When viewed through a technological lens, focus has been primarily placed on improving the usability and functionality of simulation tools, identifying barriers to adoption and understanding ways building design professionals interpret energy analytical parameters. Attia et al. [31] surveyed architects and engineers on their experience of building performance simulation tools when simulating energy use. The study found that engineers were mostly concerned with the quality and accuracy of the outputs, while architects preferred being able to compare alternative outcomes from more than one source. Moreover, architects viewed building performance simulation and energy modelling tools as an aid to learning about the building needs and a way to prioritise decision making, while engineers viewed it mainly as a way of testing approaches. Soebarto et al. [33] surveyed over 100 architects in the USA, India, Australia and the UK, focusing on their views of building performance simulation more broadly, rather than specific tools. Most participants described not conducting building performance simulation or energy modelling within their firms, with some architects not seeing the task as their responsibility. Lin et al. [14] evaluated design professionals' adoption of energy simulation technologies with the aim of visualising and predicting performance of sustainable buildings more effectively. Behavioural factors underpinning adoption decision making were identified, including perceptions of technology utility, operational complexity and potential competitive advantage [14]. Lack of education [34] as well as social barriers to adoption and effective collaboration in the context of building performance simulation were also articulated as posing difficulties in building design professionals' effective energy design [35].

While the studies above have gone a considerable way to demonstrate the role of tools and technology in simulating energy use in design, a growing body of work has offered a counterpoint to this dominance, presenting a more complex analysis. Abdelmegid et al. [36] argued that adoption of building performance simulation in architecture, engineering and construction (AEC) is limited internationally despite its capacity to provide valuable insights into building energy performance decision making due to the influence of design professionals' intuition, experience and knowledge. Some studies suggested that the role of architects for instance in the context of energy use reduction, must transcend purely technical solutions and engage more meaningfully with users, providing opportunities for co-creation [7,37,38].

An emerging body of evidence highlights the importance of better understanding building design professionals' motivations and assumptions on a number of important issues, including energy, when designing buildings - how energy and a space might be used, who may inhabit the spaces, what its spatial and environmental qualities might be [39]. Hetherington et al. [40] argued that the study of architects' perceptions of energy provides a view of buildings as composed of objects, while energy modellers' perceptions reveal buildings conceptualised as thermal zones. Oliveira et al. [41] suggested that architects' perceptions of energy use are characterised not only by technological but also social and organizational processes involved in different sized firms and projects. While these studies begin to provide an expanded understanding into design professionals' interpretations of energy beyond use of tools and engagement with data, there has been less focus placed on the visual precepts and inner mental models involved.

Nonetheless, studies in product design provide useful insights gained from the study of design professionals' visual precepts and imaginaries related to energy in designing products, reflecting on assumptions design professionals hold in visualising society's interactions with energy in daily life, in order to create more meaningful aesthetics. Their research is inspired by the concept of affordances, which refers to the increased social experimentation, learning and interaction with an object's form and functionality to produce new uses and experiences, thus contributing to varied aesthetics of use that can form over time. One prototypical example that emerged from Backlund et al.'s. [42] study is ‘The Element’, which offers a re-thinking of the aesthetics of a radiator.

In addition to product design research, studies into design professionals' visual perceptions of sustainability offers helpful insights into the analytical benefit of studying energy. Lockton et al. [43] examined sustainable design to change user behaviour and reduce environmental impact, proposing a multidisciplinary toolkit for design idea generation. Disciplinary “sources of inspiration” [[44], p.525] were argued to influence multiple factors in sustainable design thinking including ethical issues, shifting professional roles, structural anchors, context definition, and how ideas are triggered [43,44]. Another dominant strand of discussion focused on design professionals' perception of sustainability through the lens of technology, with an emphasis on accessibility and perceived usefulness to translate and facilitate design thinking [14,33,45].

While there has been some emerging work in the context of product design and wider sustainability issues, overall there is an overlooked area of research in building design related to conceptualising energy. Yet there is an established body of work focused on the perspective of users. While not seen from the lens of those who design, these studies offer helpful empirical and theoretical insights into the conceptualisations and meanings associated with use of energy in buildings.

3. Conceptualising energy use – user perspectives

Energy use has been described as holding meanings, associations and important perceptions related to a range of behavioural contextual, spatial, and social issues from alleviating pain, fresh air, personal care to zoophilism, and social signalling [46]. There is a well-established body of literature focusing on user perceptions of energy use across a wide range of building typologies, including domestic, commercial and educational settings [7,10,47]. Particular emphasis has been placed on the importance of individual perceptions, meanings and associations in relation to energy use practices and how these are implicated in wider social dynamics, norms and values both within and beyond built environments [48–50]. This has been largely viewed through the lens of behaviour change [13]. Here, perceptions are being considered in the context of a) effectiveness of information or measures provided on use [51,52]; b) 'intermediaries' of use via devices and apps [53–55]; and c) user comfort and wellbeing [12,56,57].

A focus on changing individual knowledge through information or incentive provision, is foregrounded in Abrahamse et al.'s [51] study of energy conservation, while Revell and Stanton [58] suggested the importance of information in the context of technology use. Here the potential range of householder mental models of central heating systems was shown, varying in technical accuracy. Studies on participants' perceptions of the effectiveness of energy use 'monitoring', 'ratings' or 'savings' measures noted the effects of energy reduction and saving activities [59] as well as estimation practices [60]. These studies highlight the need to better understand those mental models, perceptions and strategies implicated in energy consumption and saving judgements.

In addition to perceptions on measures and information related to energy use, studies have also examined the social and cultural dimensions of devices. For example, smart home technologies, with most insights highlighting user engagement and interaction with device functionalities [55,58] and awareness of comfort and wellbeing changes [55,61]. Hargreaves et al. [54] studied feedback strategies provided by smart energy monitors which offer visual representations of energy use, finding that while knowledge of consumption is increased, it does not necessarily lead to a reduction in energy use. Yang et al. [62] considered the application of smart technology to control temperature in homes, finding user participation curtails over time, resulting in reduced potential for energy saving as smart systems require ongoing user engagement to 'learn' occupant schedules and needs. In their study of smart technology and user values in the home, Haines et al. [55] emphasised the importance of user values which are associated with comfort, relaxation, and sentiment. Building user perceptions are also widely examined in relation to environmental control and satisfaction. Göçer [63] and Yun [64] argued that increased perception of control for example, in relation to thermal comfort, leads to improved user satisfaction, although evidence of energy efficiency implications is limited [64,65].

Where perceptions of energy have been taken into consideration, this has been almost exclusively based on the building user [6]. Social and socio-technical methods dominate understandings of attitudes and views, with a focus on the dimensions of information provision, intermediaries of use and comfort and wellbeing. While emphasis on the user is helpful, it does not address the critical role of those implicated in design, construction, or technology installation processes. The focus of this study is to address these overlooked insights based on exploration of building design professionals' ways of seeing energy. The following section discusses the methodological approach undertaken, followed by the findings and conclusion.

4. Methods

4.1. Methodological approach

This research adopts an exploratory, interpretive, qualitative research method using participant-led photography [66–69]. Participant-led photography is defined as a process by which participants use cameras to take photographs that are literal, metaphorical, symbolic, and meaningful to them, based on a brief given by the researcher(s) [75]. These images generate rich narratives weaving together various strands of why they had been taken, how they had been taken, the object, place, or person depicted, the photographer's intention, framing, and many other contextual attributes of their creation. The photographs then generate textual narratives during the photo-elicitation interviews.

This method was chosen as it aligned with the ontological and epistemological foundations of the study, the concern being with the building design professionals' (the participants') perceptions, interpretations, and imaginings of energy use in HE buildings.

This methodological choice was also made in order to foreground the participants' voice [68,69], helping their thoughts and experiences to be communicated [70,71], and creating a more balanced power dynamic between them and the researchers [72]. By placing the camera in the hands of the participants, this method offered an opportunity to explore the intangible, 'invisible' parts of energy use – such as how this is visualized or interpreted as part of the design process in HE building projects – rather than relying on textual narratives alone [66]. As noted earlier in this paper, energy itself is an intangible concept so a method that provides an opportunity to literally 'visualise' and 'see' such a concept was found to be appropriate.

The HE sector was selected as the empirical setting as it benefits from ownership of large estates in localised areas [15] with HE buildings emitting 25 % more carbon than average UK office buildings and thus having the ability to shape sustainability outcomes and offer implications for wider society [73]. In addition, design for efficient energy in HE buildings is particularly complex and requires early engagement from both architects and engineers [74].

4.2. Data collection

The initial participant contacts were obtained through a call for participation that was advertised via social media including LinkedIn and professional body social media pages such as the Royal Institute of British Architects (RIBA), within which the first author is a member, as well as engineering groups such as CIBSE. The call included a description of the purpose of the study and participant requirements including experience of working in the HE sector for over 5 years, post qualification. The description of the purpose of the study included an overview of the study background as well as how to get involved via submitting photographs and participating in an online interview focused on understanding associations and views of energy in designing HE buildings. All participants had over 5 years' experience of higher education design and delivery and held different roles within a total of 6 firms (named as 'Studios' in Table 1), from project architects and senior engineers, to associates and directors (see also Table 1). A total of 14 design building professionals participated in the study and each participant captured 8–10 images (more than expected). By speaking to a range of roles, broader insights were gained; this reduced the risk of the data being biased to a particular project or approach [75].

All participants were asked to provide 2–3 photographs, as below,

Table 1
Data collection sampling.

Role	Studio	Experience of HE sector
ASSOCIATE ARCHITECT	Studio 1	Limited to 2 projects
DIVISIONAL DIRECTOR (ARCHITECTURE)	Studio 1	Range of projects
BOARD DIRECTOR (ARCHITETURE)	Studio 1	Range of projects
BOARD DIRECTOR (ARCHITECTURE)	Studio 1	Limited to 1 project
DIRECTOR (ARCHITECTURE)	Studio 2	Range of projects
DIRECTOR (ARCHITECTURE)	Studio 2	Limited to 1 project
SENIOR ENGINEER	Studio 3	Limited to 1 project
ENGINEER	Studio 3	
ENGINEER	Studio 3	Range of projects
DIRECTOR (ARCHITECTURE)	Studio 4	Range of projects
HEAD OF ENGINEERING	Studio 4	Range of projects
SENIOR ENGINEER	Studio 4	Range of projects
ARCHITECT	Studio 5	Limited to 2 projects
ENGINEER	Studio 6	Range of projects

prior to participating in a semi-structured one-to-one photo-elicitation interview. All participants were asked to use their own cameras and were provided with the following instructions:

- Take 2 or 3 photographs that represent how you see and/or imagine energy use when designing buildings;
- Take 2 or 3 photographs that represent how you see and/or imagine energy use in HE buildings;
- Consider 'energy' in the broadest sense, rather than in terms of very specific design processes;
- Photographs can be taken from a range of sources whether from a building project you are or were involved in, or from other sources such as your everyday working practices, family life, or your own photo album.

All participants were also provided with guidance on taking photographs including capturing photographs responsibly – e.g., if an image contains people, obtaining necessary permissions before capturing or sharing photographs. Participants were also asked to not provide photographs of confidential material which invades another person's privacy or contravenes their organisations' confidentiality policy (for example, visible contents of documents or computer screens). This study was reviewed and approved by the institutions ethics committee and all participants consented to the use of their anonymised quotes and images in research, teaching materials and publications. This study was also guided by the IVSA (International Visual Sociological Association, where the second author is a member) Ethical Guidelines for Visual Research.

Over 100 photographs were provided by participants and emailed to the researchers. After sharing their photographs, participants were invited to take part in a recorded 45-60 min online photo-elicitation interview. The photo-interviews were conducted on MS Teams with researchers asking participants to initially briefly talk through their current role and experience of working in their firm and in the HE sector. This was then followed by a discussion of the photographs provided by the participants which were viewed on a shared screen during the Teams interview. The contents of the images guided the questioning and therefore the questioning route for these semi-structured interviews emerged in each interview, however, core questions included:

- Before we start could you tell us a little about your background and current role?
- Could you describe the photograph? What is happening in the photograph?
- What does this photograph mean? Why did you choose that particular photograph to say something about energy use?
- What do you feel the picture tells or conveys about how you imagine energy use in building design?
- Why is this important to you? Why is it meaningful?
- What does it make you think of when you look at this photograph?

In each interview, the focus of discussion was on the photograph selected as a way of conveying how energy was visualized in design and use of buildings. Participants were asked to explain how they selected the photographs, why they selected them and what was deemed

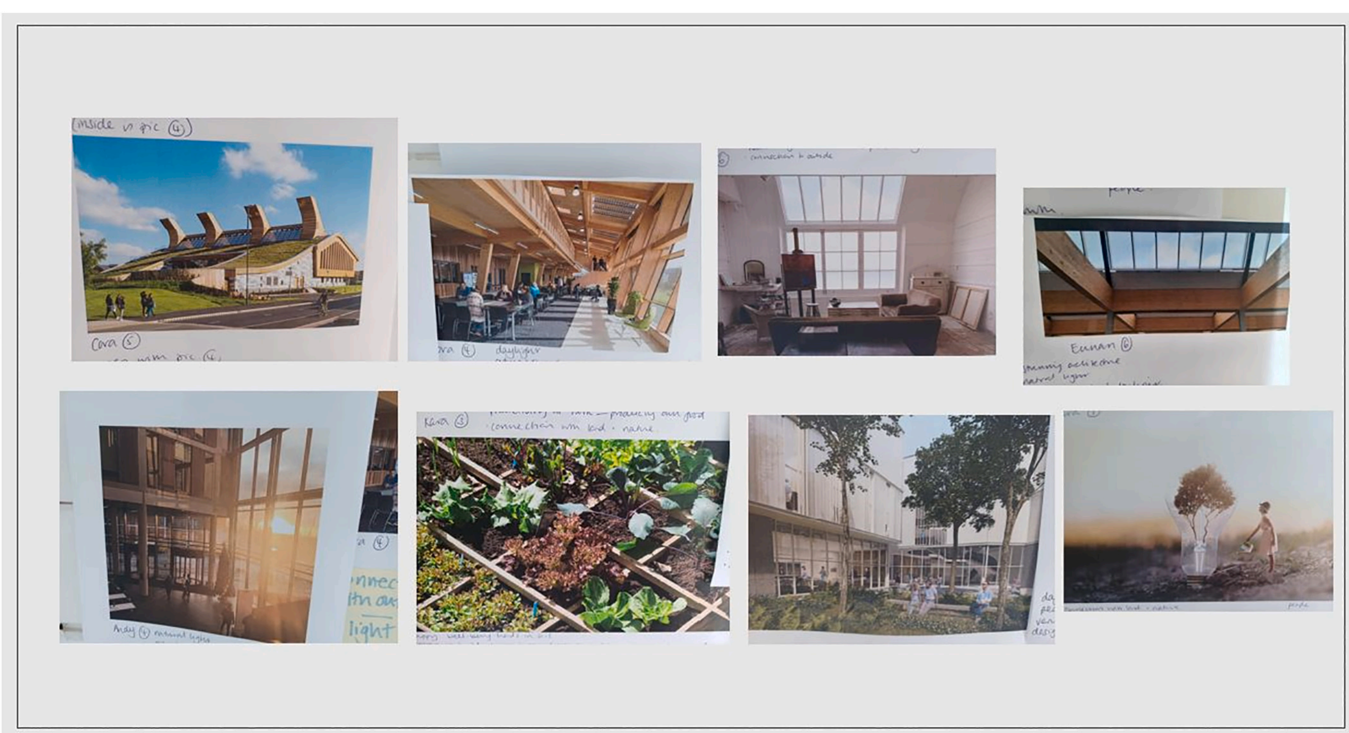

Fig. 1. example image set for theme 1 'Convincing and Persuading'.

important to convey in terms of energy, what they saw in the photograph, what the image conveyed to them, how it made them think and feel about energy, and how it represented energy for them.

4.3. Data analysis

The method of analysis used in this study followed Shortt and Warren's [76] 'Grounded Visual Pattern Analysis' process which integrates the meanings given to the photographs by participants (textual narratives), and the content of the photographs themselves/what they are of (visual narratives). The principles guiding the first part of the analysis are rooted in the ethical commitment to the participant's voice – the meaning is not 'in' the image; the photographer needs to explain its significance [77]. The participants viewed their photographs digitally on a laptop, taking time to talk about each one of their photographs in turn, the meanings they held in relation to energy, and why they captured them. Thus, the first stage in this analytical process is 'dialogic' and involves 'photographer-led meaning attribution', where photographs are coded according to the meanings given to them by the participants. For example, and in relation to the data presented in this paper, codes attributed to some photographs were; 'easy to understand', 'convince client', and 'persuade others'.

The second part of the Grounded Visual Pattern Analysis process involves grouping all the images that have similar meanings, in order to create a collection of images called an 'image set', each of which creates a theme. This approach brings together all the images that communicate a similar meaning, as established in the dialogic stage but from different participants. In the case of the study described here, for example, the codes given to some images were 'easy to understand', 'convince client', and 'persuade others', and consequently the image-set/theme generated was 'Convincing and Persuading'. The other themes discussed in this paper, 'Connection with Nature' and 'Unpredictability and Flexibility', emerged in the same way.

This grouping of images provides the researchers with the opportunity to see how the dialogical meaning has been visualized, and *how* participants have chosen to communicate their meanings. At this stage the researchers re-examine the visual contents of each image set based on what was captured in the image. This is an important part of the visual analysis as it allows the images to be brought back into the analytical process, as opposed to simply being used as prompts during the photo-interviews. The images in each theme/image set are therefore viewed in their entirety, and a 'final exposure to the whole' [[78], p.44] allows for patterns to be seen and similarities and differences to be acknowledged. In Shortt and Warren's [76] Grounded Visual Pattern Analysis process this viewing of the entire image set is called a 'structured viewing' and involves two approaches – a 'symbolic' viewing, where researchers are encouraged to see what has been captured to signify the dialogic meaning and what similarities and/or differences (i.e. patterns) can be seen across the images set in relation to this; and a 'compositional' viewing, where researchers are encouraged to see how the photograph was made and ask "are there similar framings, camera angles, positions of photographer, aesthetic effects…across the image-set?" [[76], p.551], what might this tell us about how the photographer/participant has made sense of what they are communicating? Therefore, it is at this stage that we asked: what material objects/spaces has the participant/photographer used to communicate their meanings, associations, and assumptions about energy? Is there anything striking or unusual? What patterns can we see here in relation to what has been used to communicate meanings around e.g., 'Convincing and Persuading'? We also looked for patterns in relation to how the images had been taken, how the participants placed themselves in relation to the image, and if any artistic effects had been used.

It is following this structured viewing that researchers are then able to engage in what Shortt and Warren [76] define as the final stage in the analytical process – theorising. Here we ask how do the patterns identified in the image sets augment the discursive meaning attributed in the dialogic phase? How do the patterns identified generate field/sample level meanings beyond the interpretations of individual images? And how do these patterns speak to the theoretical commitments of the wider project and provide new contributions to theory building? So, for example, the contents of the images associated with the 'Convincing and Persuading' theme included diagrams, tables, graphs, and numbers – the 'patterns' here speak to the importance and significance of data and graphics when 'convincing and persuading' others in relation to energy use. There is a formality and function to how these building design professionals conceptualise energy use when communicating with others and these images are tools that are used to show how to meet targets or model functions. The lack of people, the photographer themselves, or anything organic in this image set suggests that in order to persuade and influence people, energy must be represented in ways that are anonymous and de-humanised. Thus, from our dialogic data we know that participants seek to persuade and convince clients and those they work with, but it is only after a visual pattern analysis that we see patterns in *how* individuals go about this. Using Grounded Visual Pattern Analysis as a process of making sense of the images and what they mean, we can therefore say 'more' about *how* designers go about convincing and persuading others and *why* this might be significant in our wider understanding of conceptualising energy use.

Table 2 below maps out the analytical process described above and uses a worked example of the theme 'Convincing and Persuading' to illustrate. The table indicates the stages of the analysis as dialogic, grouping, structured viewing (symbolic and compositional), and theorising.

5. Findings

Overall, three key themes emerged from the Grounded Visual Pattern Analysis. All participants tended to convey ways they conceptualised energy through either particular aspects of design whether initial stages and engagement with clients or more general inspiration or motivation for energy efficient design drawn out of nature, family or natural materials. Energy was in summary conceptualised through a particular context whether professional or personal. Although it was thought that there may be disciplinary variation between architects and engineers, this did not emerge in the findings with differences instead being in emphasis placed on either the professional context of conceptualising energy or a more personal one.

For some participants, it was important to convey energy as seen in a professional context and in their early discussions with clients or other consultants where thinking on energy is being explained through diagrams, data, and graphs. For these participants conceptualising energy involved activities of persuading and convincing and use of technical diagrams and data. Theme 1 *[Convincing and Persuading]* included conversations and images that conveyed participants' conceptualisations of energy as seen in the context of discussions they would have with clients and other consultants. The theme is characterised by images of a largely technical nature – often anonymous and de-humanised – void of people or context.

Participants conceptualisations of energy were also associated with more general earthly imagery of nature and landscapes. Theme 2 *[Connection with Nature]* is concerned mainly with participants' imaginings and perceptions of energy beyond particular project scope or client/consultant relationships. Conversations conveyed an emotive connection with the images – often of caring and protecting nature, with images that conveyed family members and stories of experience and everyday life and activity – in stark contrast with Theme 1 that portrayed a business-like, 'means to an end' perception of energy as seen in conversations with clients.

In contrast to both themes 1 and 2, some participants focused discussion on conceiving energy through particular details and building components specific to the HE sector. Theme 3 [*Unpredictability and Flexibility*] focused mainly on the HE building type and energy

Table 2
Illustration of the analytical process: Grounded Visual Pattern Analysis – adapted from Shortt and Warren [90].

Stage	Key questions/decisions/conceptual considerations	Worked example from this research
1. Dialogic	The researcher and participant viewed participant's images online, using Teams. Images represent how designers visualise and imagine energy use in the design process/in relation to Higher Education (H.E.) buildings. Images address questions like, 'what matters to you when thinking about energy efficiency in the (H.E.) design process?' High degree of participant reflexivity. At this stage, the meaning(s) of the image is generated through discourse around the image – not what it is 'of' or what is 'in' the image, but what it *means*.	Conversations/interviews with designers included narratives around being able to 'convince the people I work with', 'it makes it easy to understand', 'it makes it easy to visualise', 'this makes it simple', 'process is driven by data so users… visualise in a meaningful way', 'clients can visualise', 'that process of convincing …making things clear to clients'. The thematic analysis of the interview transcriptions therefore suggests **'Convincing and Persuading'** (theme 1, discussed below) is key to how designers think about energy efficiency in the H.E. design process.
2. Grouping	Creating image-sets based on the meaning/theme associated with the image(s). Relevance of the image to the grounded theme e.g., discursive meaning generated during the dialogic stage above.	All images associated with the theme **'Convincing and Persuading'** were grouped together. The purpose of doing this is to generate a collection of images that were all taken to communicate a particular issue identified at the dialogic stage (1). This offers a chance to look at how the dialogical meaning has been visualized, offering a window onto the underlying meaning. This first step is necessary before analysis can begin. See Fig. 1 below for an example of an image set associated with this theme.
3. Structural viewing	**Symbolic viewing:** what patterns are apparent from what is depicted? Anything striking or unusual? What is foregrounded or backgrounded or omitted by the photographer? **Compositional viewing:** how has the photographer framed the image? Placed themselves in relation to the scene? Used artistic effects e.g., camera angle, filters? Enrolment of the material into the visual communications. How are the spatial practices of the photographer communicated in the image? *What* did designers choose to represent these feelings/what matters to them?	A symbolic and compositional viewing for the theme **'Convincing and Persuading'** includes: 1. infographics 2. diagrams 3. tables 4. graphs 5. lines 6. boxes 7. arrows 8. numbers 9. bullet points 10. computer generated images 11. no faces 12. no people
4. Theorising	How do the patterns identified in stages 2–4 augment the discursive meaning attributed in the dialogic phase? How do the patterns identified generate field/sample level meanings beyond the interpretations of individual images? How do these patterns speak to the theoretical commitments of the wider project and provide new contributions to theory building?	From our dialogic data we know that designers seek to persuade/convince clients and those they work with, and make energy efficiency in buildings 'easy' to understand, but it is only after a visual pattern analysis that we see patterns in *how* individuals go about this. 1. When designers think about persuading or influencing clients with regards to energy it comes in the form of data and graphics. This is about communicating complex information, quickly and clearly 2. The formality/data driven/functional aesthetic contrasts with the social/human feel of the 'connection with nature' theme (2)/photo-set (Fig. 4) 3. Images are of extremes about how it should be or shouldn't be/standards/targets and modelling vs an everydayness or sense of reality 4. Images associated with 'understanding' energy are digital/data driven 5. To convince clients you need graphs and stats – these are the tools used to convince others 6. Talking to clients/customers about energy is not associated with people or something organic 7. Raises assumptions that in order to persuade and influence people, energy must be represented in ways that are anonymous and de-humanised 8. Sense of feeling 'sure' and 'certain' that these images will persuade 9. Assumptions that graphs and digitally produced images will have the power to influence and enable understanding – assumption that clients will not understand without these tools

considerations within Higher Education design as one of multi-functionality and needs that varied across time and space as well as between different types of users. Themes are discussed in greater depth in the following sections.

5.1. Key themes

5.1.1. Theme 1: convincing and persuading

Throughout the conversations, some participants explained their choice of photographs as driven by what they saw as 'initial conversations' with clients, about energy, at the start of a project. They referred to seeing considerations on energy use in design as something that needed to be explained and justified through numerical data. They referred to these as early discussions they have with clients and other consultants during the course of a project. During these discussions participants observed that they often feel the need to not only explain a particular aspect of the building design including on issues of energy use, but need to '*convince*' others of their decision making with regards to energy.

As part of this need to justify, participants use specific images to 'persuade', 'influence' and 'convince' their audiences, helping them visualise why or how decisions about energy use in the building are being made. For these participants issues of energy were associated with provision of images that in their eyes convince. For example, one architect said, in relation to the images below (Fig. 2):

'…you do need proof for clients…to be able to say why you need to do this. It's not about beautifying something for the sake of it. I think this first

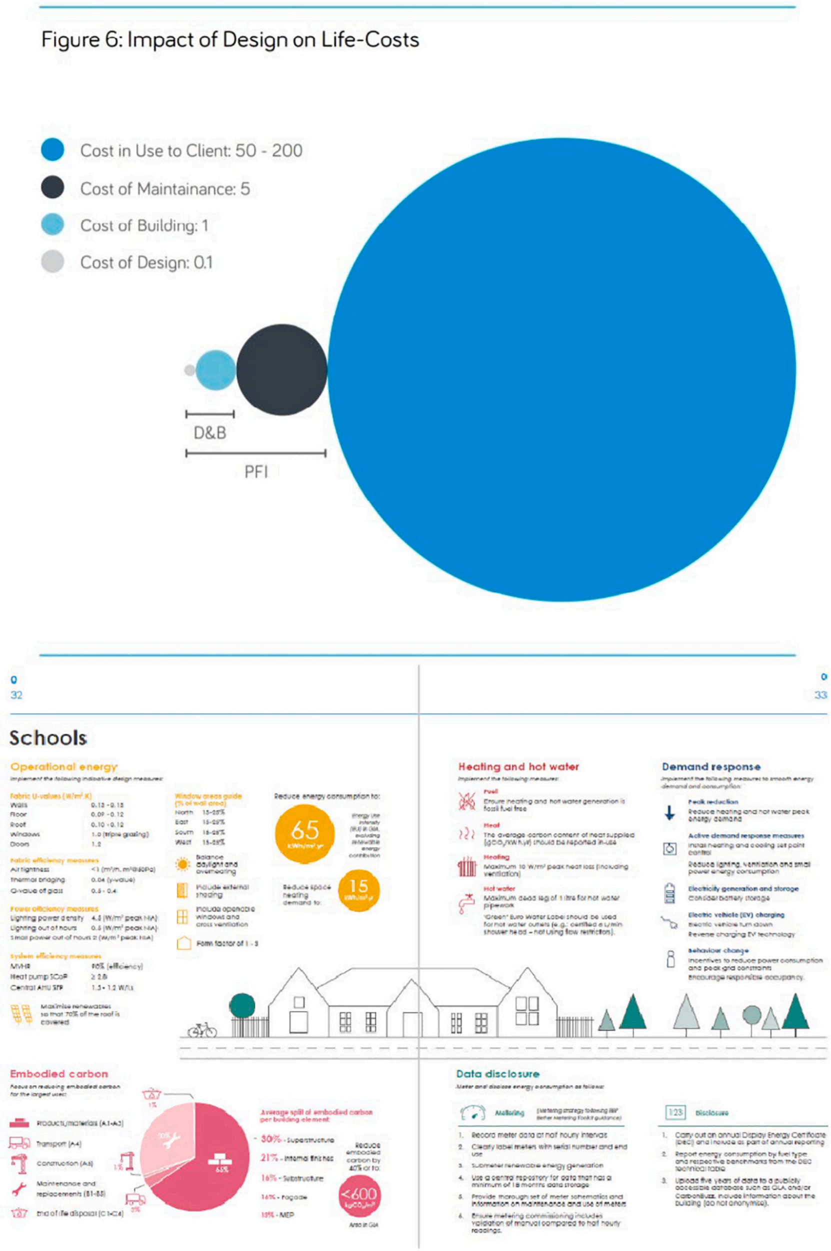

Fig. 2. images used by an architect to talk to her clients.

image is useful to be able to start conveying that conversation' and '[with clients] …*we need to be able to have a conversation to bring those things into focus…I just find it a really useful snapshot …to be able to set targets which are not in an ambiguous manner. If our clients don't have a baseline they understand well enough…we'll use this'*

It seems these images are tools and resources building design professionals use and draw upon, in order to assist client's understanding of

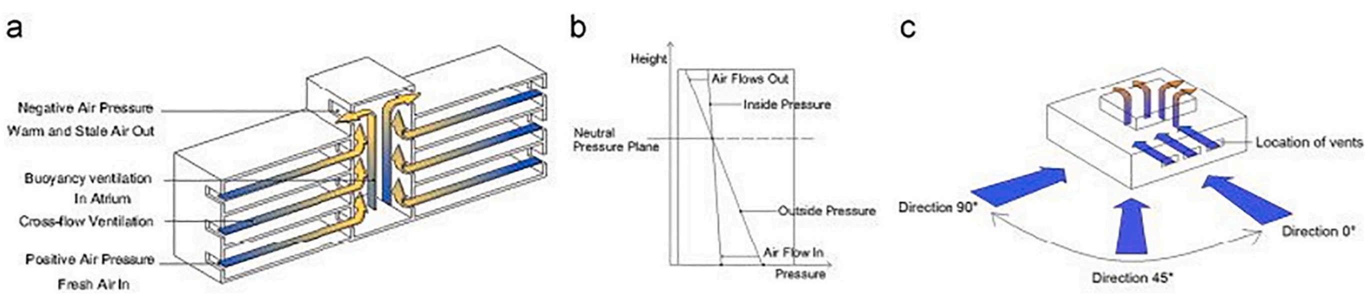

Fig. 3. an architect's image of making things 'easy to understand' for a client.

energy. What is particularly striking about the content and composition of these images is that they are all technical and largely monochromatic in some way. They include diagrams, computer generated images, mapping, and infographics, where bullet points, arrows, numbers, and boxes help to convey ideas and plans. As our participants explained, these images are used to influence others in the design process and communicate 'complex information quickly and clearly', as another architect explained, in relation to Fig. 3 below:

> *'...it's just visually easy to understand...images like this really portray the fact that the stack fit works....so you're trying to persuade them you know the benefits of using this design...at the early stages of the process.'*

There is certainly an assumption here that to understand energy use, building design professionals need graphs and statistics to represent standards and targets. From the visual analysis of these images, it is clear that this digitally based information sharing is devoid of anything emotive, contextual or social. These images are in some sense anonymous and de-humanised (there are no faces, or living things represented in the images), and as such we can conclude that when these practitioners are talking to clients about energy use, the visual material used is often void of place and people. How energy use is designed and negotiated in a project is thus perceived and 'seen' as a technical, external, functional issue and does not appear to encompass social or emotional factors. Interestingly, one engineer reflected on his comments at the end of the interview and seemed to ponder on this very issue, noting *'...you asked questions I didn't necessarily expect...it's almost putting the emotions into engineering which has never happened, but I think it needs to be there...'*.

5.1.2. Theme 2: connection with nature

In stark contrast to the findings above, some participants when asked about what matters when imagining and visualising energy, represented this through connections they had with nature and natural materials, including natural light, green spaces, earth, wood, people, and users (often familiar to them), windows, sky, and plants.

These participants talked about their preferred use of natural materials in their work, such as the landscape, the light, and the soil. They discussed conceptualising energy use as something intrinsically linked to nature and the earth. There is a sense of warmth, both in the images captured here and in the conversations with these building design professionals, where their aesthetic appreciation for all things 'organic' and 'familial' emerged. Throughout our conversations, participants used far more emotive language than when they had been talking with clients or others in the design process. It seems that when they are reflecting on their *own* assumptions and motivations regarding energy use, they use far less functional, technical language and instead talk about being 'happy', 'pleased', 'glad', 'inspired', 'healthy', and 'appreciative'. For example, one architect talked at length about the links she makes between the land, nature, and energy. She said, in relation to Fig. 5 below:

> *'...putting our hands to the soil brings us back to the present moment which helps well-being...we see gardening as a hobby rather than something that's meant to feed us...this light bulb* (see Fig. 5 below) *represents that...separating a person and nature, that's healing that relationship with nature and finding ourselves back in the system. To me it's about including aspects of vision in the designs...consciously including spaces that you grow food...it's all about dragging people back to the grid...so when we start talking about energy it's not just about the power, the electricity, but it's about people themselves'*

From our visual analysis of these images, some feel far more 'snapshot' in style and have a more 'everyday' aesthetic, in comparison to the formality of the infographics and technical images discussed above. As such, there is evidence here to suggest that the participants' stories, assumptions, and motivations regarding energy use are multidimensional and conflicting. When it comes to talking to *others* in the design process (Theme 1 above), energy use is something that is represented through technical drawings and images, yet when participants talk about how *they* feel (note the language throughout this theme includes phrases like 'to me' and 'I think personally') and imagine energy use, it is in a far more introspective way; it is represented and connected to emotive and social factors.

One engineer spoke with great feeling and enthusiasm about the image below (Fig. 6), and said:

> *'...this is the atrium in the engineering building ...it's a stunning piece of architecture...it really made it...we have lights in the atrium but they're never going to be on during the day, there's no need for them...with the amount of natural light coming into this space. I just think every building should have more natural light. We should really be maximising ...it's so*

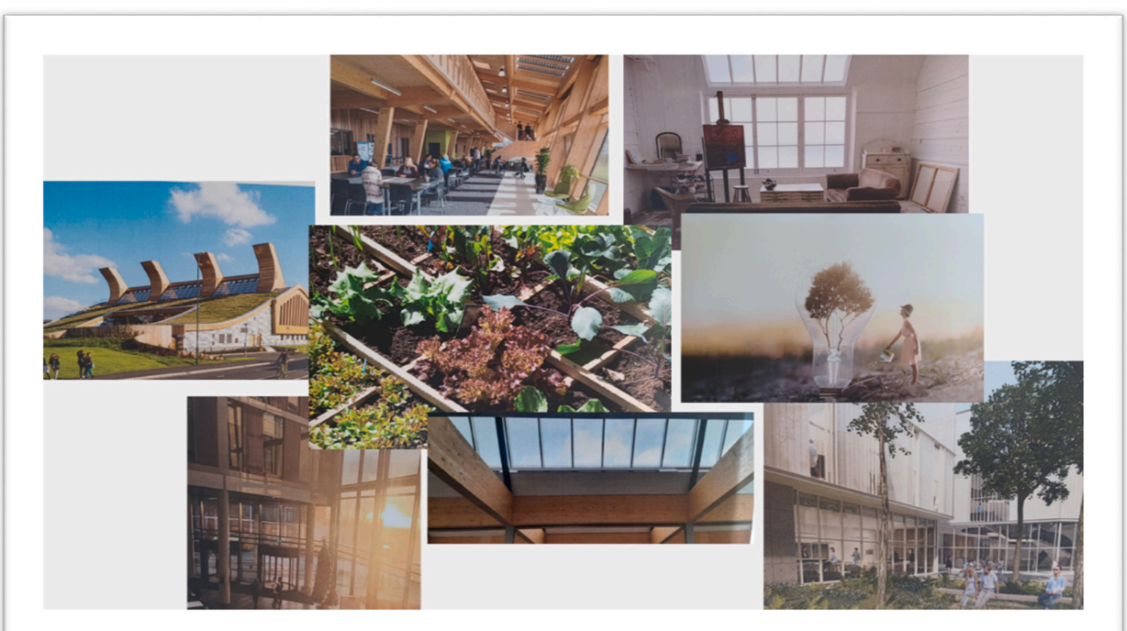

Fig. 4. example image set for theme 2 'Connection with Nature'.

Fig. 5. an architect's image of our relationship with nature.

Fig. 6. an engineer's image of natural light.

healthy for us. It just shows we don't need to consume energy if buildings are designed correctly then we will operate without having additional systems that aren't really required'.

An architect also reflected on the natural light in a building and talked about the difference between considering the technical, thermal images and the 'lived experience' of natural light. He said, in relation to Fig. 7 below:

'I personally think it's [natural light] *really important in buildings. I think you know having that connection between inside and out, and actually reducing the amount of artificial light you use…is always a massive benefit. It's interesting…we had a thermal image that we had discussions about …but the people actually running the café said they were getting a lot of glare coming through at certain times of day…and we hadn't got solar shading on the thermal image because the thermal model didn't say we needed it. So, yeah, natural light is a big thing but it's the lived experience that matters …'*

These are interesting contradictions that serve to highlight some of the professional and personal constraints and opportunities that currently drive the design process and how, in the future, we might move to a more holistic practice that takes account of the emotive and social *as well as* the organizational and technical.

5.1.3. Theme 3: unpredictability and flexibility

Another overarching theme that emerged from our conversations with designers was the way they associated with energy through the unpredictability and flexibility of energy use needs of HE buildings (Fig. 8).

When talking about energy use in HE buildings, some participants were at pains to explain how complex such spaces and buildings are, given the variety of people who use them, their often multi-functional uses, and the need for flexibility and constant change. Throughout conversations, participants noted the need to be able to respond to 'user needs' and 'the people' and to 'better understand behaviour in HE spaces'. This flexibility and diversity in design adds a layer of complexity to the design process, when coupled with thinking about energy use. As one engineer explained, in relation to his image of a lecture theatre (Fig. 9 below):

'It's a room which is absolutely full of people so it represents an asset which is being used to explore capacity…there's probably interesting conversations to be had with HE clients about the use of diversity in the building design so, for example, if we're providing lots of fresh air to try and keep CO^2 down and improve people's concentration should we really be designing that on the basis that all the rooms are full all at the same time? Is that how the building actually works or should we be designing for something which is a little bit more typical? I mean if you were designing a commercial office building…you

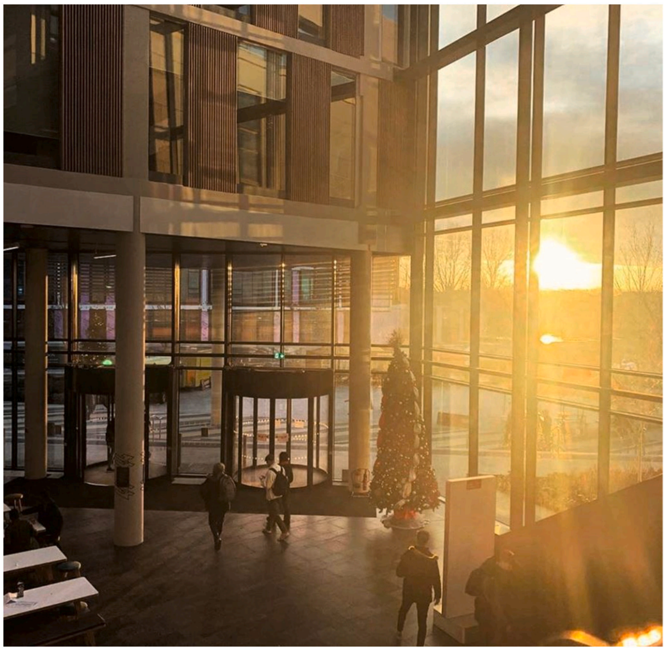

Fig. 7. an architect's image of natural light.

design a building to have 20% of people absent, so I wonder whether the same could be applied to education? …the other thing which I quite like about this image is everyone is looking in the same direction. Everyone's doing what you expect them to do…but buildings are complex and people are complex particularly in big groups and I think it's probably quite rare that everyone's doing what you expect them to do. So, it's sort of…this image is about a need for a better understanding of people's behaviour…in buildings…'

The images captured as part of these discussions show largely 'everyday' shots of internal spaces that include lecture theatres, classrooms, and accommodation, as well as chairs, coffee tables, steps, and sofas. In many of the images there are groups of people and students and the participants noted that part of their job is accepting that although they design a space in a particular way, they never know how users will respond to it. For example, one architect used the image below (Fig. 10) to talk about the adaptability of HE spaces and how this indirectly links to energy use:

'This is the orchestra playing in the Business School……a nice example of adaptability…I thought what a brilliant use of that flexible space and it did make me appreciate actually, you know, making that space completely flexible that you could move all the furniture out the way. It sort of did respond to the needs of people using the building and it was a really nice thing…It made it a really vibrant sort of space and I suppose the whole idea of a space being adaptable means that it can be used and reused and the life of the building is elongated in a way …so in a sense it is sustainable, its saving energy because …hopefully you won't be pulling the building down and making significant changes and all the embodied carbon and energy that goes in with that'

From our visual analysis of these images, compositionally, they depict long shots and helicopter views of HE spaces, suggesting that overviews, or rather strategic, views of such spaces are important and should be understood holistically when thinking about energy use. Once again, the everydayness and social factors represented in the images for this theme offer another contradictory juxtaposition with the functional images used to influence clients (Theme 1 above). Thus, unpredictability and flexibility seem to be a 'reality', whereas what is used to influence and persuade clients are images of 'predictability' and what is perhaps 'expected'.

6. Discussion and conclusion

The study aimed to examine the associations or assumptions architects and engineers draw on when thinking about energy use in buildings as well as to understand what conceptualisations meant to them. First, the findings reveal the externally facing and internally held conflicting and contradictory processes that embody building design professionals'

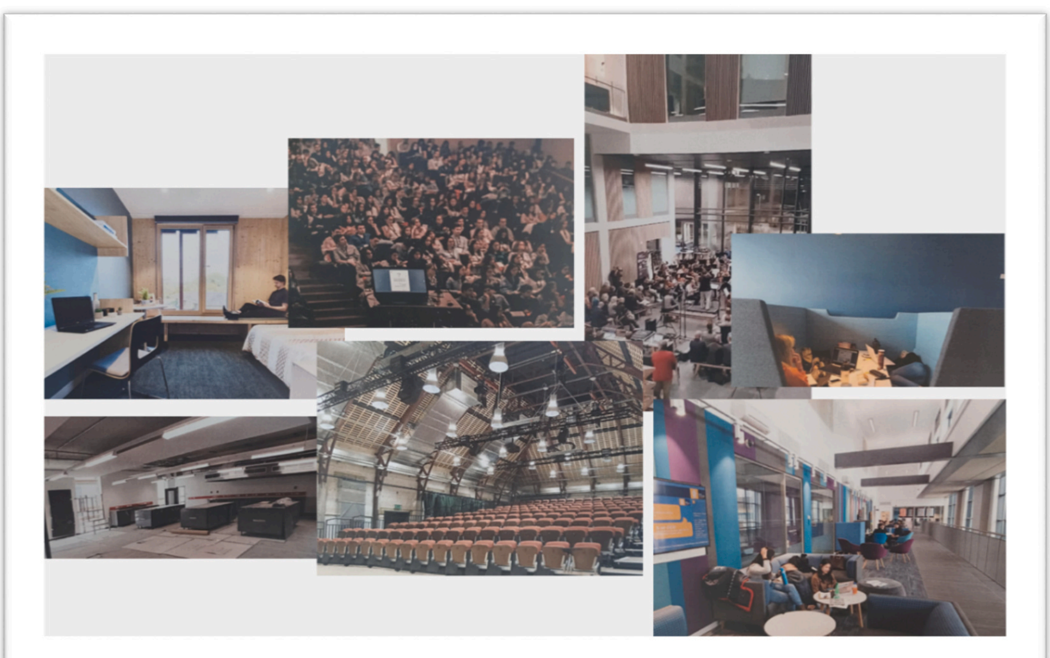

Fig. 8. example image set for theme 3 'Unpredictability and Flexibility'.

Fig. 9. an engineer's image of complexity in HE spaces.

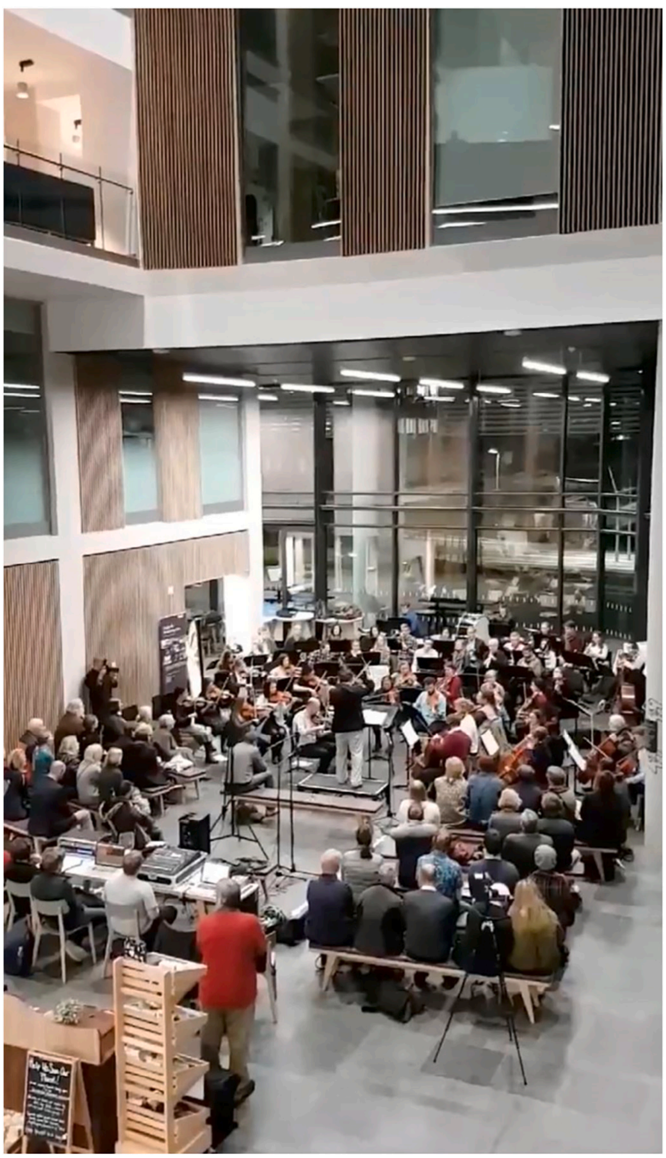

Fig. 10. an architect's image of adaptability in H.E. spaces.

associations with energy. While Lymer [79] suggests that designers require a 'double vision' – the capacity to visualise both within and beyond the scope of professional parameters, the processes that underpin this double vision specifically on environmental and social concerns such as energy, remain poorly understood. The findings of this study offer experiential energy design insights, suggesting that the lived experience of practicing building design professionals is one of emotion, contradiction, and internal conflict between professional and client expectations, and core personal values and motives related to experiences of family, nature, people, and history. Overall associations building design professionals draw on when thinking about energy in design embody both a highly professional context represented through graphs and data as well as a deeply emotive, personal, familial and earthly context connected to nature and people. Research to date drawing on a mainly technological lens as discussed above [2–4, and] have overlooked the significant implications personal, deeply held emotive thinking on energy may have on design decision making, building performance as well as user comfort [29].

Within Theme 1, *Convincing and Persuading*, building design professionals conceptualise energy use within the design decision making process, as a static and predictable function of building design, supported by statistical data and graphics which are considered necessary for effective communication with clients. On the other hand, Themes 2 and 3 reveal design professionals' internal conceptualisation of energy as bounded in connections with nature and inherent flexibility and unpredictability of HE spaces. This contradiction between internal values and perceptions of professionalism and client expectations, provides novel insights into the complexity of how design professionals 'see' energy use and suggests opportunities for more holistic and co-creative design practices. Though previous studies have already identified the need to understand this process more holistically [38,80], the ways these processes are experienced are still poorly understood. This is surprising given that creative problem-solving of complex interconnected issues such as energy lies at the heart of the design processes [39,81].

Second, the findings consider how these internally held ways of 'seeing' inform understandings of energy in ways not yet fully explored in energy research more generally. Studies of design thinking, emphasise the integration of bodily engagement into design processes [82] and recognise the importance of emotive work and its wider implications. Few studies, however, consider these factors in relation to energy and specifically in relation to those who use spaces and systems designed, such as building users [36]. While a great deal of energy research has established the social and increasingly digital socio-technical engagements with and through energy use [83] as well the behavioural dynamics encompassed [47], few have sought to understand the visual and inner mental categorising involved. While studies have suggested that perceptions of energy are informed by people's social context, relationships and held values and meanings ascribed to activities through which energy use takes place [6,8], there have been few studies that have tried to consider how these meanings are represented and to characterise the lens through which they are viewed. This paper provides transformative insights into conceptualisations of energy that are on the one hand static, technical in nature and void of humanity justifying or indicating something predictable and controllable as conveyed in Theme 1. On the other hand, a greater portion of photographs in Themes 2 and 3 conveyed a warmth, connectedness with nature, protection of nature and people as an emotive, deeply held understanding of energy. These conceptualisations suggest an unpredictability and dynamism that seem difficult to bring to conversations with clients and the design process itself.

Third, this study's visual research lens offers a point of departure to shed greater light on the visual and emotive underpinnings shaping perceptions of energy. Though there have been numerous calls for novel methodological approaches into studies of energy [46,84,85] few have explored the use of visual research methods in this context. The participant-led photographic method drawn upon in this study provides an approach which engages more explicitly with the 'invisible' in energy, and the emotive and deeply held aspects of design, largely overlooked in the context of energy use.

There are also implications for practice and policy. Findings reveal conflict and tension between the ways in which building design professionals frame and communicate energy use to clients, as a technical, anonymous process, while their social and emotive imaginings of energy remain personal and hidden from these communications. This has important implications for design practices and processes whereby professional bodies and energy policy have tended to emphasise the need for technical advancement and energy literacy as a technological capacity [86,87], with little or no consideration for the social and emotive issues involved. Future work might help expand how these less expected images of nature, people and caring for landscapes are associated with energy use in buildings and how these conceptualisations could inform design processes and practices that may enable a more equitable, emotive, and potentially meaningful realisation of buildings efficient use of energy in ways not yet made possible.

While this study offers novel empirical insights into conceptualisations that shape energy use in buildings, there are some limitations and areas for future research. It would be helpful to further expand this work in other building typologies such as schools and offices as well as the domestic sector as they increasingly have consequences for decarbonisation transitions. Also, this study is based on building design professionals based in the UK. It would be helpful to carry out future work that involved international cross comparison whereby the professional and policy or regulatory context of design and construction might be different. Further research is also needed to help explain the characteristics of the paradox, conflicts and contradictions found within ways building design professionals see energy within a number of contexts in the built environment across other building typologies as well as in other sectors. This is important given energy systems are being designed and redesigned such as in smart grids, other sources of energy supply and distribution, transport systems, as well as food and distribution of resources. Such studies could offer greater knowledge of how energy systems and technologies are initially imagined, communicated and the emotions and feelings that embody that process, as well as what gets left out, what is negotiated and what remains a material presence that shapes all our lives.

Future work could also draw on visual research methods to better understand users' mental models and how energy is 'seen' in everyday use in a range of contexts. Such work could help inform new ways of thinking, designing, and using energy systems and technologies that underpin daily life. This could include enabling emotive work and embodying contradiction and conflict as part of design negotiations and conversation, perhaps new systems of energy could be envisioned and created that are in tune with and respond to needs of nature, family, and everyday life in more connected ways.

Declaration of competing interest

All authors declare that they have no conflicts of interest.

Data availability

The data that has been used is confidential.

Acknowledgments

The authors would like to thank all the participants who took part in this study as well as UWE Grant for Growth G4G Fund and partners involved for providing support for initiating the pilot for the study.

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