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Workplace Energy Culture Framework: A Mixed Methods Study Examining Differences in Energy Use and Behaviours within an Industrial Workplace

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Abstract: One way to achieve energy efficiency in the workplace is to change employee behaviour. Research in this area is limited, and significant gaps remain in understanding differences in how energy is used within workplaces and the suitability of existing frameworks for application in workplace settings. This paper addresses these gaps by applying and further developing the interdisciplinary energy culture framework (ECF) to examine employee energy use in an industrial workplace with an office and manufacturing areas. A mixed methods approach consisting of surveys, a focus group and interviews is applied. Results show significant differences in the office and manufacturing areas, with office areas having a more energy-efficient energy culture. Qualitative results show differences exist due to organizational behaviours, such as the effectiveness of business communications methods, varying levels of investment, the physical environment and work tasks. Results also show external influences, such as government budgets, business structure, and wider organisational cultures, impact energy cultures and how energy is used. This paper proposes modifications to the ECF, which acknowledges the multi-scalar nature of workplace energy cultures. This paper demonstrates how the ECF can be applied to workplace settings, allowing further understanding of how energy is used, and identifying wider organizational, occupational, and individual psychological influences on energy use.

Keywords: energy culture framework; workplace; energy efficiency; energy use; energy attitudes; non-domestic; organizational behaviour

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1. Introduction

Reducing the impact of human-induced global warming and reaching net-zero carbon dioxide emissions is critical to limiting global temperature rises [1]. Achieving this requires reducing energy demand and supply across all sectors, including industry and businesses [2]. Industry and businesses are large emitters of greenhouse gas emissions, consume large amounts of energy, and account for 14% of all UK GHG emissions [3].

Reducing energy use in workplaces can be achieved in two ways: technological improvements or changing employee behaviours [4]. Technology improvements are frequently the primary approach businesses take, due to the ability to quantify and justify investments and understand the amount of energy savings before investment. However, ‘people use energy, not buildings’ [5]. It is widely acknowledged that workplaces are more complex environments when compared with domestic settings [6,7], with employees often not being aware of the amount of energy they use—there being no direct financial consequences associated with increased energy use by employees; multiple employees often using the same work equipment; and workplace priorities often competing with energy efficient behaviours [8–10]. However, employees are a captive audience, and there is a lot of potential to reduce energy demand and improve efficiency in the workplace [8] and a potential for spill-over behaviours to other environments [11]. Zierler, et al. [12] propose that individuals in organisations are as diverse as those observed in the domestic setting, and workplaces need to recognise the diversity of attitudes across staff populations. There is no 'one size fits all approach' for engaging or changing employee energy use, and more research is needed.

A recent review looking at the interaction between occupants and buildings for energy efficiency identified that a lot of workplace research has often focused on offices, educational establishments, and healthcare facilities [4], and there are calls for more research into employee energy behaviours that goes beyond focusing solely on office employees [13]. Significant research gaps remain in examining sector-specific research [6] and applying mixed methods research to examine occupant energy behaviour, with most research to date focusing on observed occupant behaviour rather than why or how behaviour is generated [14]. The limited research conducted in manufacturing workplaces primarily focuses on manufacturing technologies and energy efficiency processes [15], rather than on employees or taking a whole system approach. To succeed in reducing business energy demand and achieving net zero, there is a need to understand the magnitude of factors that influence energy use in all work environments and fill these research gaps.

This paper addresses some of these research gaps by applying a mixed methods approach to examine energy attitudes and behaviours of employees at a site of a large multinational security and defence manufacturer, which hosts a mix of office-based and manufacturing activities. It makes three distinct contributions to knowledge. First, empirically, it details how the attitudes and behaviours of employees differ between office and manufacturing areas within a workplace in the UK. Secondly, theoretically, it demonstrates how the 'The Energy Culture Framework' (ECF) [16,17] can be applied to workplace settings to gain an understanding of how energy is used and which occupational and organisational psychological factors influence the energy use of employees. Thirdly, this paper proposes modifications to the ECF to facilitate future applications in work environments by researchers, practitioners, and policymakers, which could ease the identification of and understanding of external influences on energy use and the impact they may have at varying scales in the workplace.

The structure of this paper is as follows. Section 2 reviews research that explores employee energy use, workplace energy efficiency, and the frameworks and approaches applied to examine them. It concludes by discussing the ECF applied in this paper. Section 3 describes the mixed methods and analytical approach. Section 4 presents quantitative and qualitative results, demonstrating differences in results from office and manufacturing areas and discussing why differences may exist. This section concludes by presenting a revised ECF for applications in workplace environments. Section 5 discusses the findings and implications of these results, the study limitations, and opportunities for future work.

2. Literature Review

A recent systematic review by Cibinskiene, et al. [13], examining which determinants of energy consumption in public buildings are most studied, identified three main research strands: research focusing on psychological and social determinants, socio-demographic determinants, and contextual determinants. They call the first two groups 'individual predictors', while the third group is 'situational predictors'. Norton, et al. [18] apply a similar grouping in their work, identifying obstacles to pro-environmental behaviour in workplaces with the categories of individual characteristics or organisational settings. Based on these categorisations, this review is structured into the following four sections: (1) employee behaviours (which focuses on the individual); (2) organisational culture and sustainability (which incorporates the situational and organisational settings); (3) barriers to workplace energy efficiency (which crosses both employee and organisational categories); and (4) existing frameworks that have been applied to examine energy use in the workplace.

2.1. Employee (Occupant) Behaviours

There is a well-established body of research examining the determinants of individual energy use and barriers associated with energy efficiency; however, much of this focuses on the domestic environment (as others have noted [10,13,19–21]), with fewer applications concentrating on the work environment.

The workplace is a more complex environment than the domestic setting, with competing work demands, multi-personnel workstations and a lack of direct financial incentives to reduce energy use [6–10]. Employee behaviours can differ from inside work and at home [19,22], and business decisions can directly shape employee energy behaviour [6].

Research on employees, sometimes called occupants, often focuses on how socio-psychological constructs, such as individual environmental concern, subjective norms (the perceived social pressure to perform or not perform a behaviour) [23] and broader workplace attitudes, can impact pro-environmental behaviours. Several authors apply theoretical frameworks that incorporate these constructs, including for example, the theory of planned behaviour (TPB) to examine energy behaviours [9,24–29] (more information on TPB in the next section).

Empirical research suggests a positive relationship between personal norms, subjective norms, energy-saving knowledge, and intention to save energy in the workplace [13]. Weerasinghe et al. [30] also found occupants' perceived behavioural control (the perceived ease or difficulty of performing a behaviour [22]) and perceived knowledge to perform occupant energy-related behaviours were correlated with subjective norms, organisational support, behavioural interventions and accessibility to control. The influence of other people (such as colleagues) [13] and employee motivation [31] play a significant role in energy-saving processes. Li, et al. [31] also highlight how creating a favourable organisation and interpersonal environment that supports energy-saving behaviours is important in office environments. These findings highlight how employee energy use is determined by various socio-psychological constructs, along with workplace-specific factors, such as other employees and the physical environment.

Examining if consumer and domestic behaviour frameworks can be applied to organisational settings, Zierler, et al. [12] examine the energy efficiency behaviours of individuals of a large UK infrastructure operator. Reporting on a cluster analysis approach, they identified five different employee groups within one organisation: the technology sceptic group, efficiency-aware participants, the barrier-sensitive group, the organisational barriers group, and the benefit sceptic group [12]. These findings highlight how employee energy efficiency behaviours are not uniform within an organisation, and show that employees within a workplace have different views and respond to workplace processes differently. Others have identified how employees can differ and call for more research that goes beyond examining office employees' behaviour [13]. In testing a benchmarking tool developed to further understand energy behaviours in the workplace Ucci, et al. [32] identify some differences in office and manufacturing environments. They find statistically significant differences in questions that examined the self-reported behaviour of employees, social norms, energy training, supervision, perception of the company's energy policy, and individual beliefs and attitudes.

In highlighting the importance of social relationships within the workplace and the role different individuals can have in energy use, Isaksson et al. [25] examined employees who act as 'drivers' to energy efficiency improvements, and considered their social relations with other employees. Often, 'drivers' are part of a facility, e.g., environment team or facilities management, but the results highlight how this is not always the case. Isaksson et al. [25] highlight the supporting role co-workers can have when 'drivers' put forward suggestions or attempt to encourage energy efficiency. This work also identifies how the relationship between drivers and co-workers is not static and is constantly evolving. This supports the notion that employees can become active drivers of sustainable transitions within organisations [33,34] and that some employees (e.g., drivers) can have a greater impact on other employees' energy behaviours than others.

2.2. Organisational Culture and Corporate Sustainability

There is a well-established body of literature on organisational culture and a growing body of work on corporate sustainability and its associated culture [35–37]. However, most research focuses on either one or two aspects of organisational culture [38], and often fails to take a broader whole systems approach.

Organisational culture plays an integral part in the sustainability of a workplace and often goes beyond compliance and regulatory requirements [38]. Bulińska–Stangrecka et al. [15] identify the leadership, sense of community, collaboration, and business structure as being important cultural dimensions that affect green workplace practices. Wijethilake et al. [38] identify other cultural dimensions and propose four competing categorisations of organisational change that can shape organisational sustainability: people-oriented changes (e.g., empowerment, training, development, team orientation, leadership), growth-oriented changes (e.g., sustainability innovations, continuous improvements, community engagement), productivity- and efficiency-oriented changes (e.g., use of professional recommendations, open communication), and stability- and control-oriented changes (e.g., sustainability budgeting, investment appraisal, life-cycle assessment). The variety of changes noted here demonstrates the array of organisational influences on the sustainability of the business and employees, ranging from being directly employee-focused to being economic and investment-focused.

Some argue that organisations need to change their mindset and integrate environmental and social dimensions of sustainability into strategies and business priorities [39] to become more sustainable. However, efforts to implement organisational change are sometimes limited, due to the technocentric approaches many organisations take [40]. Mouro et al. [41] found that when organisations invest in pro-environmental policies and practices, workers' commitment to pro-environmental behaviours is reinforced. Additionally, organisational interventions, such as introducing energy-saving guidance and training and incorporating environmental values in business development philosophy, can improve employee energy-saving attitudes, subjective norms, perceived behavioural control, and employees' intention to conduct energy-saving behaviours [28]. It is beyond the scope of this paper to discuss in detail the variety of ways organisations can improve energy efficiency, but readers are directed to Ruparathna et al. [42] for a detailed systematic review highlighting the variety of organisational, management, behavioural, and operational and technical changes that can be applied.

A recent review by Unsworth et al. [43] discusses the interplay between organisations and employees and their role in helping the environment. While reiterating several of the points already discussed in this review, such as the complexity of the workplace, the role of employee values and attitudes, and changes organisations can make, such as introducing training and guidance, they also highlight the important role managers play. Managers act as a link between the organisation and the employee [43]. Their work behaviours and how they conduct tasks play an important role in other employees' environmental behaviours [44]. Additionally, the support and guidance they give has also been shown to influence environmental behaviours [45].

2.3. Barriers to Workplace Energy Efficiency

In addition to the literature that focuses on either the employee or the organisation, there is a body of work that focuses on the barriers to energy efficiency and maintaining energy efficiency (e.g., [33,34,46–52]). A lot of this work focuses on the workplace as a whole, often focusing on technical barriers, with little or no focus on the barriers associated with improving efficiency at an employee level. Barrier research aims to identify and understand barriers, which can then aid researchers, workplaces, and policymaker understanding, with the aim of addressing these barriers, which will lead to efficiency.

Focusing on the organisation, there are a variety of barriers to pro-environmental behaviours, such as a non-green internal culture, non-authentic goals, lack of autonomy and exemplary role models, lack of support and the influence of wider colleagues and supervisors, lack of communication [33,47,51], lack of internal resource or low capacity of facilities management [47,51] and lack of policy drivers [33,47]. Several of these barriers can be associated with the influence of subjective norms. Please see Yuriev et al. [51] for a more detailed review of workplace barriers and recommendations on how to overcome them.

Employee or individual barriers can include the level of personal commitment to the organisation, the influence of social norms; perception of existing infrastructure; time, lack of knowledge of how to act; self-efficacy; an unwillingness to change habits; a lack of broader awareness of environmental problems [51]; and no direct financial consequences for individuals [33]. The barriers identified here further highlight the complexity of employee energy use and the variety of interacting factors that can affect employee decision-making.

2.4. Existing Frameworks

A review examining the research approaches that have been applied to study employee energy and heating behaviours in buildings identified the theory of planned behaviour (TPB) [23], the value belief norm theory (VBN) [53] and the norm activation model (NAM) [54] as being the most widely applied [55]. Additional frameworks with applications in the workplace include the motivation-opportunity-ability framework [30,31], which incorporates social–psychological aspects of NAM and TPB [31]. The TBP argues that behaviour is a function of four themes: attitudes towards the behaviour, subjective norm, perceived behavioural control, and intention, which interact to create a given behaviour [23]. The VBN incorporates the norm activation model and argues individual choices or decisions can be explained by personal values, the ecological worldview [56], awareness of adverse consequences, and the ascription of responsibility to self and personal norms [53]. Both theories are well-established approaches to examining occupant behaviour in domestic environments and demonstrate a range of socio-psychological factors, which interact to define a given behaviour.

When applying the TPB or the VBN, existing research often fails to capture and acknowledge the broader complexities of the workplace and the myriad of factors that may be influencing employee energy use, which are outside of the TPB or VBN theories. Supporting this, Heydarian et al. [55] call for research to move beyond the commonly applied theories and explore how applications of other theories and frameworks could further assist in furthering understanding of the role of behaviours in building systems.

Energy Culture Framework

In light of this, this study applies the interdisciplinary ECF [16,17] to examine employee socio-psychological constructs, energy attitudes, and behaviours in the workplace. The framework argues energy use can be understood by examining the interactions between three core elements: Material Culture, Practices, and Norms (Figure 1). Material culture represents the physical environment, infrastructure, technologies, and structures that play a role in how energy is used. Practices are the tasks and behaviours that are completed that use energy. Norms are the expectations, aspirations and shared beliefs of a given practice and material culture.

The framework provides an opportunity to understand the broader external influences that shape the material culture, norms and practices. External influences present opportunities or challenges where any of the three core interacting elements can be altered. They could take the form of policies, campaigns, regulatory standards, individuals, structures, and all influences that can change the core elements, and subsequently change the energy culture. Identifying external influence on energy cultures highlights opportunities, where change can be made to subsequently alter one or several of the core elements (material culture, norms, practices), and subsequently modify the energy culture. The ECF addresses several gaps in existing techno-economic studies by examining cultural identity [57], while also addressing limitations of studies that fail to explain real-life energy behaviours and the complexity behind energy behaviours [58].

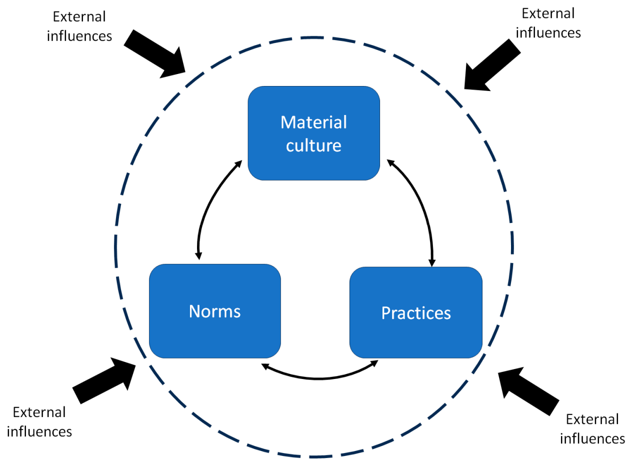

Figure 1. The energy cultures framework [16].

The ECF has been applied to a variety of research topics, such as examining firewood and cooking practices [59], transport mobility [60], understanding participation in energy programmes [61], and energy use and production in the domestic setting [62–64]. The framework has been less widely applied in the workplace setting. It is outside the scope of this paper to provide a detailed review of all the applications of the ECF but, in focusing on applications in work environments, Dew, et al. [65] applied the ECF to examine how complex organisations (US Navy) make decisions about adopting energy innovations. They found decisions about energy efficiency improvements are firmly rooted in the prevailing energy cultures of an organisation. They note that while sometimes there may be economic and operational benefits that support the adoption of efficiency measures, existing ECF characteristics associated with energy topics being 'backgrounded' in day-to-day activities can lead to a delay in the roll-out of energy efficiency measures, as shown, for example, by the roll-out of LEDs taking over a decade [65].

Tseng, et al. [66] apply a modified ECF to understand how academic air travel behaviours are shaped and influenced. They conclude that academic flying practices are embedded in complex systems, which are affected by wider society, the physical environment (location to transport infrastructure), work institutions and the individuals at the core of the ECF. Bell, et al. [67] applied the framework to examine the socio-technical barriers to using energy-efficient timber drying technology in New Zealand. They find the industry has a dominant culture that supports vented kilns and marginalises heat pumps, making moving away from vented kilns challenging. Oksman et al. [68] used the ECF to develop a survey to aid organisations in understanding their sustainable energy culture. Employees and energy managers of organisations can complete the survey. Oksman et al. [68] argue results can be used to determine the maturity of different aspects of business sustainability energy culture.

These examples show the breadth of application of the ECF in workplace settings, ranging from Bell et al. [67] and Dew et al. [65], who apply the framework to examine the energy cultures of a specific industry/type of employer, to Tseng et al. [66], who use the ECF to examine individual travel behaviours. There is yet to be an application of the ECF in a workplace environment that examines the broader external influences on an individual's (employee's) energy use. Oksman et al.'s [68] survey addresses the employee aspect of business sustainability but is limited by the questions it explores. It does not incorporate broader social–psychological constructs such as subjective norms which, as highlighted in Section 2.1, can significantly impact individual energy use.

Addressing the research gaps identified in this review, such as a lack of research on energy behaviours that focuses on non-office employees [13], the lack of applications of the ECF focusing on employee energy use, the need for more sector-specific research [6], and a need for research to go beyond the commonly applied theoretical frameworks [55] and consider systems perspectives [43], this paper applies the ECF to examine employee energy attitudes and behaviours. In doing so, it also examines the interplay of external influences and their role(s) in energy culture(s) within the workplace. The following research addresses two main research questions: RQ1. How do manufacturing and office employees' energy attitudes and behaviours and energy cultures differ? RQ2. To what extent can the ECF be applied to the workplace to aid understanding of employee energy use and the wider external influences on energy use?

3. Method

To address the research questions, a sequential exploratory mixed-methods [69] approach consisting of quantitative surveys, a qualitative focus group and an employee interview was undertaken. The survey, designed to examine employees' energy attitudes and behaviour and the external influences on these behaviours, addresses RQ1. The qualitative and quantitative results are used to address RQ1 and RQ2. Figure 2 illustrates the steps of the empirical process. Given the limited research on energy use in this sector and restricted site access (further details below), applying a mixed-methods approach enables the researcher to better understand the workplace environment [70]. It provides an opportunity to comment on broader external influences on workplace energy cultures, which may be overlooked when applying a primarily quantitative or qualitative approach. All data collected adhered to GDPR, and care was taken to ensure the anonymity of participants (more details below).

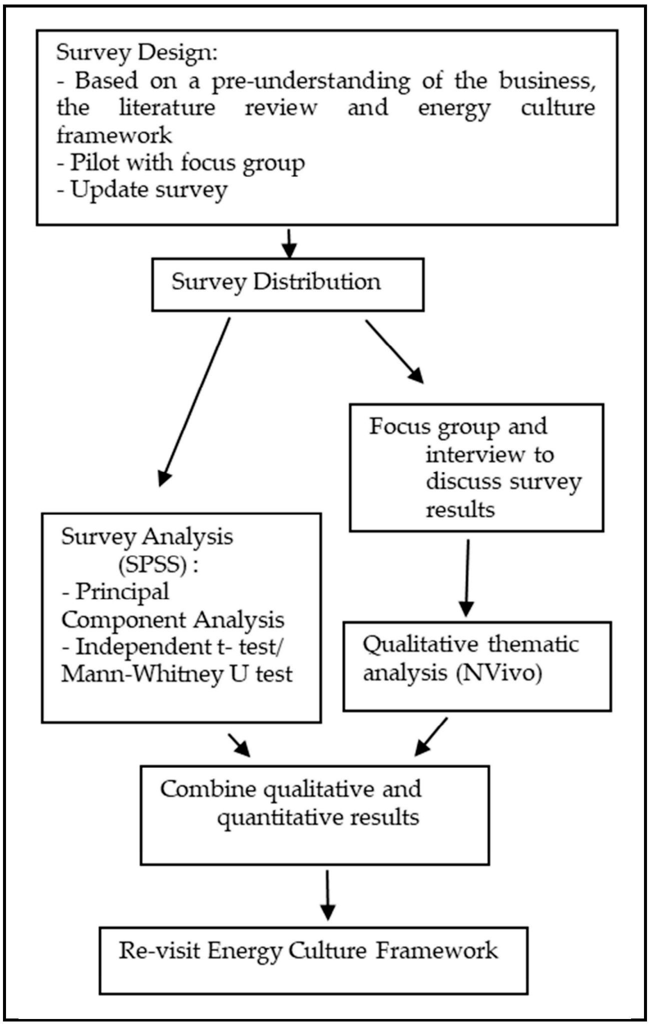

Figure 2. Visualistaion of main steps of the study methodology.

This study collected data at one site of a multinational security and defence manufacturer. The site is in northwest England, UK, and hosts a mix of office and manufacturing facilities, employing approximately 2000 people. Employees are generally classified as office- or manufacturing-based. This classification forms the basis of examining RQ1.

Issues associated with commercial sensitivity and national security relating to the nature of the industry prevented direct access to the site and employees. 'Gatekeepers' [71,72] were used to gain access and facilitate data collection. There were two key gatekeepers in this work: the first, a long-serving (+35 years) member of staff whose job role related to developing business energy and sustainability projects, and the second, a member of the SHE (Safety, Health and Environment) team whose responsibilities included site sustainability and environmental issues.

3.1. Survey Design and Analysis

3.1.1. Survey Design, Measurement and Distribution

The survey was developed to address RQ1, examine the 'norms' and 'practices' core themes of the ECF (RQ2), and explore the wider external influences on workplace energy cultures. In keeping with other studies that explore energy attitudes and behaviours in the workplace, questions from Dixon et al. [9], Chen et al. [29], and Ucci et al. [32] were adapted and included in the survey (further details on question development can be found in the Supplementary Information. Table 1 details questions included in the analysis). Both Chen et al. [29] and Dixon et al. [9] draw on the TPB in their question development, while Ucci, et al. [32] build on a variety of established theoretical frameworks in their question development. Survey questions were five-point Likert scale questions ranging from Strongly Disagree to Strongly Agree. Socio-demographic questions, including which building the participant worked in, were also included.

Table 1. Results from the PCA identifying eight components (groups) and the associated Cronbach Coefficient Alpha, Eigenvalues (λ) and percentage variance explained by each component.

Group	α	Questions	λ	% Cumulative Variance
1—Employee attitudes and subjective norms	0.89	Q10b Within my specific work team we are conscious of our energy use	0.77	20.60%
		Q10d Within my work environment energy use and demand are discussed regularly	0.72	
		Q10e I discuss ways to reduce energy use and demand with my work colleagues	0.70	
		Q10c Within my specific work team we regularly try to reduce our energy use	0.69	
		Q10h I would be well thought of by my colleagues if I took action to save energy at work	0.69	
		Q10a My line manager influences my energy use	0.64	
		Q10g I would be well thought of by my line manager if I took actions to save energy at work	0.63	
		Q10f Colleagues within my work environment support the need to reduce energy use	0.61	

Table 1. *Cont.*

Group	α	Questions	λ	% Cumulative Variance
2—Employee energy suggestions and feedback	0.97	Q9h If I make a suggestion on how to reduce energy use and demand it will be taken seriously	0.95	29.77%
		Q9i If I make a suggestion, I will receive a response detailing any changes or reasons for not implementing the suggestion	0.95	
		Q9j Employees are encouraged to make suggestions which can reduce energy use and demand	0.93	
		Q9g If I have a suggestion on how to reduce energy use and demand at work I know who to speak to	0.89	
3—Concern of business energy use, demand and cost	0.78	Q9c Reducing energy demand should be a higher priority for the business	0.73	38.44%
		Q9a Energy demand is an important issue for the business	0.69	
		Q9d Reducing energy use should be a higher priority for the business	0.69	
		Q9b Energy use is an important issue for the business	0.64	
		Q13a I am concerned about the cost of energy to the business	0.42	
4—Home Energy Practices	0.89	Q14e At home I always make an effort to reduce energy use	0.75	43.64%
		Q14c At home I always leave electrical goods off at the mains socket when not in use	0.63	
		Q15a At home I am concerned about rising energy prices	0.56	
		Q14a At home I always turn lights off after I leave a room	0.54	
		Q13b I am concerned that rising energy costs will affect my day-to-day tasks	0.46	
		Q15b At home rising costs have affected my day-to-day tasks	0.46	
5—Workplace Energy Reduction Practices	0.80	Q12a At work I always turn equipment, which I personally use, off after I have finished using it	0.85	48.06%
		Q12b At work I always turn equipment off at the end of the day/shift	0.81	
		Q12d At work I always make an effort to reduce energy use within the workplace	0.54	
		Q12c At work, if I am the only person in an area, I always turn lights off after I leave that area	0.44	
6—Workplace Energy Reduction Knowledge	0.70	Q13f It is clear to me who is responsible for switching off the lights	0.74	51.04%
		Q13e It is clear to me who is responsible for switching machines/equipment off during downtimes	0.60	
		Q13g If I wanted to turn equipment/machines off in my work area I know where the relevant switches are	0.44	

Table 1. *Cont.*

Group	α	Questions	λ	% Cumulative Variance
7—Workplace Energy Approaches	0.78	Q8b I have received enough training on energy saving at work	0.67	53.67%
		Q8a I get enough supervision and guidance on saving energy at work	0.65	
		Q9f It is clear to me what the business are doing to reduce energy use and demand	0.49	
		Q8c I know the amount of energy my team/department use	0.41	
8—Role of the SHE function	0.74	Q1da The SHE function influence how I use energy in work	0.68	56.21%
		Q1db I associate energy related topics with the SHE function	0.65	

The survey was piloted with the gatekeepers and a focus group of employees on site. Focus group participants were asked to complete the survey in the session and encouraged to ask questions if they had any during survey completion. After completion, they were asked to provide feedback on the survey's design. During the focus group, some participants gave brief explanations for their survey answers. These explanations provided valuable insights into the daily operations of the site, and the energy use attitudes of employees. These were recorded in researcher field notes.

This pilot study highlighted the need to include further questions that examined the influence of the SHE team on employee energy use, and the business processes for employees to provide workplace energy efficiency suggestions. It also identified: (1) the need for university branding to ensure participants understood their employer was not conducting the survey, and (2) how some employees do not use computers regularly. The survey was updated to reflect these comments, and two approaches to survey distribution were developed to accommodate those who do not use computers. For more information on the pilot study, please refer to Brown [73].

Two survey distribution methods were used to ensure all employees were represented. First, an internet-based survey was developed to target employees in the office environment. A link was distributed via existing internal emailing lists. Second, to target the manufacturing areas where employees are not required to use a computer regularly, paper surveys were distributed by the researcher in amenity areas within the three main manufacturing areas on site. Manufacturing employees were offered refreshments as a 'thank you' for completing the survey. Both manufacturing and office employees who completed the survey were provided with the opportunity to opt-in to a prize draw to win one of two shopping vouchers. In total, 256 surveys were completed, representing approximately 13% of the site's employees.

3.1.2. Survey Analysis and Principal Component Analysis

Survey responses were inputted into SPSS. Likert scale responses were coded from 1 (Strongly Disagree) to 5 (Strongly Agree). Participants were coded into either office or manufacturing segments to address differences in manufacturing and office areas based on the building they stated they worked in.

Before conducting any statistical analysis to determine the significance of any differences, principal component analysis (PCA) was conducted. PCA is a data reduction method to reduce a set of variables into a smaller set of dimensions [74]; it groups questions (factors) to create a scale (component), enabling statistical tests, such as an independent *t*-test and Mann-Whitney U test, to be conducted on groups of questions [75]. PCA was undertaken on all Likert scale survey questions.

The PCA approach includes inspecting the correlation matrix, Kaiser-Meyer-Olkin test result [38], Barlett's test of sphericity values, the anti-image matrix and scree plot [75,76]. As suggested by Tabachnick and Fidell [75], first a direct oblique rotation should be conducted. If an inspection of the correlation matrix reveals no values greater than 0.3, which indicates there is less than 10% overlap in variance among factors, an orthogonal rotation can be used [75].

Sum scores for each PCA suggested components were created by summing the values corresponding to all items (questions) loaded on each component [77]. To allow comparison across components, mean sum scores were calculated by using the sum-scores divided by the number of factors in each component.

To address RQ1 and determine if any differences in results from manufacturing and office areas are significant, independent t-tests or Mann-Whitney U tests were conducted. The output of these tests indicates if any difference in the two groups' (manufacturing and office environments) means are statistically significant. The decision of which test to perform was made after an inspection of box and whisker plots to identify any outliers. If outliers were found they were removed. Additionally, the Shapiro–Wilk test was examined to assess if the data was normally distributed. If the outputs violated the assumption of normally distributed data, Mann-Whitney U tests were conducted on the whole sample (including outliers).

3.2. Focus Group and Interview

A semi-structured focus group was conducted on-site with employees from the manufacturing and office environments (n = 9). The purpose of the focus group was to gain insight into how energy is used on-site, whether differences exist between manufacturing and office environments, and, if so, why differences may exist. It was also used to understand any wider external influences on energy use in the workplace.

The focus group lasted approximately one hour and was attended by nine employees: six from manufacturing and three from office areas. One manufacturing employee had the experience of working in a more office-based role previously. All participants had worked in their roles for at least one year. Four of the group had been employed for over twelve years but in different positions. During the focus group, participants often spoke about broader environmental issues besides energy use, such as waste, water usage and broader sustainability topics. This paper refers to these as 'environmental communications'.

In addition to the focus group, an interview was conducted with a long-serving (35+ years) senior engineer who was classified as an office employee. The interview aimed to gain additional insights into office-based activities and the site's energy culture(s). The long-term employment of this individual and the associated wealth of knowledge on business structure and activities also provided further opportunity to look at broader external influences on energy use. The interview lasted approximately one hour. Questions from the focus group and interview can be found in the Supplementary Information.

The focus group and the interview were recorded (with participants' permission). To ensure anonymity of participants, any references to names were removed from the transcriptions. Transcription and a thematic analysis of the focus group and interview was undertaken in NVivo by the researcher. The thematic analysis involved coding interview and focus group participants responses by theme. Then transcripts were re-reviewed, once initial coding had been conducted to ensure responses were coded with all themes in mind. The researcher was aware of some differences in manufacturing and office environments emerging from the survey during coding. Once the survey analysis was conducted, the NVivo codings were examined to assist in the understanding of why differences between office and manufacturing areas may exist.

4. Results

This section discusses the research findings. First, the outcome of the PCA analysis is described, along with brief descriptions of the eight-factor groupings identified. Second, survey results are presented, identifying several areas where statistically significant differences exist between the office and manufacturing areas. Third, drawing on results from the focus group and interview, this section explains why differences in results may be observed. In doing so, it further identifies some differences between office and manufacturing areas, and some of the external influences on the energy cultures of the two areas. Finally, this section revisits Stephenson, et al. [16,17] ECF and, using the research findings, proposes a modified version, called 'The Workplace Energy Culture Framework', for future applications in workplace settings.

4.1. Principal Component Analysis

PCA with a varimax orthogonal rotation was conducted on the 39 factors. A total of three factors (questions) were found to have correlation coefficients below 0.3, and the rotated factor matrix identified several factors with complex item loadings. The decision was taken to remove these three factors from the analysis and these corresponded to the following statements: 'If I notice a fault with equipment I am using, I always report this to my line manager', 'I am more conscious of energy use than my work colleagues' and 'At home I always leave electrical goods on standby when not in use'. PCA was conducted on the remaining 36 factors and no further correlation coefficients were below 0.3. A total of ten components had eigenvalues over 1, which explained 61.56% of the total variance. However, an inspection of the scree plot found retaining eight components to be appropriate. PCA was conducted again on the remaining 36 factors, limiting the output to 8 components. The eight-component result explained 56.21% of the total variance. Table 1 shows a summary of the results of PCA, along with Cronbach Coefficient Alpha. Further details on the PCA approach, including information on the PCA groupings and their comparison to original survey design, can be found in the Supplementary Information.

4.2. Where Are There Differences: Findings from Survey Results

Table 2 reports the sumscore mean, standard deviation, standard error mean and median of the office and manufacturing areas for each of the eight component groupings, segmented by office and manufacturing. To determine if differences in sum-score means were statistically significant, independent t-test or Mann-Whitney U tests were conducted. Shaded rows highlight groups with statistically significant differences.

Table 2. Sum-core means (SS Mean), standard deviations (SD), standard deviation error mean (SEM) and median (M) for the eight components segmented by office (n = 120) or manufacturing (n = 136). For Groups 2–8, Mann-Whitney U results, p-values and test statistic Z are presented. Shaded columns identify statistically significant results.

Group	Area	SS Mean	SD	SEM	M	U	p	Z
1—Employee attitudes and subjective norms	Office	2.917	0.770	0.703	2.875	n/a	n/a	n/a
	Manufacturing	2.710	0.574	0.049	2.750			
2—Employee energy suggestions and feedback	Office	3.398	0.654	0.060	3.500	6049.5	<0.001	−3.602
	Manufacturing	3.088	0.628	0.054	3.250			
3—Concern of business energy use, demand and cost	Office	4.160	0.549	0.050	4.000	7269.5	0.128	−1.521
	Manufacturing	4.060	0.492	0.042	4.000			
4—Home Energy Practices	Office	3.654	0.654	0.060	3.667	8407.0	0.675	0.419
	Manufacturing	3.677	0.656	0.056	3.667			
5—Workplace Energy Reduction Practices	Office	3.447	0.535	0.049	3.600	6966.0	0.041	−2.043
	Manufacturing	3.297	0.606	0.052	3.400			
6—Workplace Energy Reduction Knowledge	Office	3.669	0.700	0.064	3.667	5846.5	<0.001	−3.972
	Manufacturing	3.311	0.798	0.068	3.333			
7—Business approach to energy topics	Office	2.971	0.649	0.062	3.000	5365.0	<0.001	−4.758
	Manufacturing	2.538	0.630	0.054	2.500			
8—Role of the SHE function	Office	3.492	0.855	0.078	3.500	5935.0	<0.001	−3.840
	Manufacturing	3.337	0.782	0.067	3.000			

An independent t-test identified the difference in office and manufacturing mean sumscores for Group 1 to be statistically significant; t(210.689) = 2.150, $p = 0.033$. Groups 2–8 did not have normally distributed data, but did have similar distributions, so Mann-Whitney U tests were conducted. Groups 2, 5, 6, 7 and 8 had statistically significant differences between office and manufacturing areas (Table 2). These findings suggest there are differences in energy cultures in these areas. Before discussing this further, it is interesting to note two groups of questions with no statistically significant results: groups 3 and 4. Group 3 examines employees' concerns with business energy use, demand and cost, and group 4 examines self-reported domestic energy-saving behaviours. This result suggests that individual concern and home energy practices are not factors that could explain the differences in office and manufacturing energy cultures.

The manufacturing areas scored lower than the office areas in all groups with statistically significant results. This means the manufacturing areas disagreed more with the questions in each grouping. These results suggest the manufacturing areas have a less energy efficient energy culture than the office environment.

4.3. Why Differences Exist: Findings from Qualitative Results

Exploring why these differences exist and gaining a further understanding of how the energy cultures of the two areas differ, this section draws on findings from the focus group, interview, and site observations. It is structured around five themes (business communication, work tasks, the physical environment, investment, and job security), which are the outcomes of a thematic analysis of the focus group and interview data. Where appropriate, insights from the wider literature are incorporated into each theme. Unless otherwise stated, quotes come from the focus group.

4.3.1. Business Communication Strategy

The workplace being examined has a top-down hierarchical structure traditionally associated with military operations, where decisions are made at a senior level (often board level), with messages transferred through the business, often via chain communications [78,79]. Results from the interview described this process when explaining environmental communications in the business. They highlight how supervisors usually attend a central meeting, where they are provided with environmental communications and site-wide environmental agendas are discussed. Supervisors are often instructed to transfer these messages to the less senior staff in DSUMs (daily start-up meetings—a brief daily team meeting approximately 15 minutes long) and WSUMs (weekly start-up meetings—weekly team meetings up to 1 h long), which often occur around SQCDP (Safety, Quality, Cost, Deliver, People) boards. These boards are located in each work area on site. During DSUMs and WSUMs, the boards act as discussion prompts, with all meetings starting with 'safety' topics then progressing through to 'people'. Senior members of staff were only very rarely approached directly with environmental communications.

This method of communication was highlighted in the focus group, along with its limitations:

> '*[its] a less effective way of [communicating]. . .because you can't guarantee [supervisors are] going to do it right. . . and you can't guarantee they're going to even do it*'.

Additionally, supervisors may experience 'goal conflict' [80], where supervisors prioritise product or safety conversations over environmental discussions. The nature of activities conducted in manufacturing areas means there is more to discuss on the topics of 'Quality, Cost and Delivery' than in office areas. This difference in the two areas was identified in the focus groups by a manufacturing employee, who stated:

> '*they (office areas) talk more around the flowery stuff like [energy]*'.

Additional forms of communications in the workplace occur via poster campaigns, webpage articles and emails. However, as highlighted in the following quote, the nature of activities conducted in manufacturing areas may hinder the reach and impact of these campaigns:

> *'All [manufacturing staff] do have access [to computers], they all have a log-on and stuff for doing online training and things like that, so some of them will log-on on a more regular basis than others' (interview).*

> *'. . . [but] stuff doesn't always get filtered through. . .we still get emails and stuff, but we don't need to look, to access them everyday' (focus group).*

Employees working in office environments use computers as a key part of their role. The previous quotes highlight the stark differences between how manufacturing and office employees interact with computers. The focus group discussions further confirmed this, with several manufacturing employees commenting that they rarely checked their work emails. These statements highlight how communication methods that utilise emails and webpages may fail to reach all employees in the same way, and could explain the statistically significant differences reported in groups 2, 7 and 8.

4.3.2. Work Tasks and the Physical Environment

Focus groups findings and observations from the site visit during the focus group show clear differences in the physical environments and work tasks associated with office and manufacturing areas. The manufacturing environments are often large shed-like spaces occupied by a mix of individual workstations and larger production line-type equipment. The shed size and age of the building vary based on the manufacturing processes being conducted and the stage of investment. Observations note how the large nature of some of the spaces and the layouts could make it challenging to determine if someone is working in a given location. This affects the ability to make energy-efficient decisions, such as turning lights off. This contrasts with office environments, where there are often rows of desks, where it is relatively easy to scan a room to determine if other staff members are in a given space and thus make energy-saving decisions, such as turning lights, heating and equipment off.

The manufacturing environments also have more complex physical environments, where it can be challenging to determine when employees have options to conduct energy efficiency tasks. There are also some manufacturing areas that conduct shift work. A focus group participant commented on how a lack of consistency in workstation layouts could prevent employees from becoming familiar with the locations of sockets and light switches. Additional complexity is associated with the nature of shift work. Shift work requires knowledge transfer between the two shift teams to ensure manufacturing processes and chain communications are not disrupted. This provides another level to the chain of communications and an additional point where information, such as that related to energy efficiency tasks, may not be transferred. Additionally, the activities of the next shift will dictate how energy is used in the current shift, for example, if equipment, lighting and heating could be switched off.

Discussing how energy is used in manufacturing environments in the focus group, participants suggested that a distinction could be made between 'shed energy' and 'employee energy'. 'Employee energy' would be related to individual workstations and energy that an individual is in direct control of, such as radios, spotlights, and individually-used machines, while 'shed energy' would consist of larger pieces of equipment associated with the production lines, and wider shed heating and lighting that employees do not have direct control of.

> *'There's lots of things out of our control. . .the bigger stuff that consumers the most energy we have no input into them, things like light switches which are probably trivial compared to [that] kit'.*

Here, the participant demonstrates a level of understanding of the energy consumption of different pieces of equipment and the challenging nature of the manufacturing physical environment. This quote also identifies a potential challenge for the manufacturing environment, namely with engaging employees in individual energy efficiency tasks, such as switching lights off, when these quotes could be seen as 'trivial' in terms of the energy they use, compared with larger equipment.

4.3.3. Investment and Job Security

Focus group discussions indicated that the level of investment an area of the business is granted and where they are in their product production lifespan could lead to differing attitudes across the site.

'Participant 1: we're in a newish building . . .

Participant 2: This is a new building, and there's a new culture, new build.

Participant 3: the investment'.

In the above extract, participants are talking about differences within manufacturing areas across the site and how different manufacturing areas have different cultures. Manufacturing areas are directly affected by the lifespan of a product or project. For example, one product might have a five-year contract for production, while another has fifteen years. In the extract above and during the conversations that followed, participants suggested that the physical environment, product lifespan, the associated investment level and job security can influence attitudes towards energy use.

> *'You're going to find differences, we've got loads of investment and have orders for the rest of our careers. . . they [other manufacturing shed] don't know what they're going to be doing in the next few years'.*

In this extract, the participant suggested employees might invest more time and effort into improving energy efficiency if they have job security for the long term and could see a future working in the business. The same could be said about office and manufacturing areas more generally, as office areas are commonly associated with the day-to-day running of the site, with staff members having contracts that are not directly related to a project's production lifespan. In contrast, manufacturing areas contracts are directly entwined with product lifespan.

The impacts of different levels of investment were noted during fieldwork, where clear aesthetic differences in manufacturing sheds were noted. Some buildings looked 'newer', with freshly painted floorings, clear signage, brighter and cleaner spaces, and modern staff refreshment areas. This contrasts with some older buildings on site, which looked dated, with items such as noticeboards appearing to be afterthoughts in design processes and tired and dated social spaces.

4.4. Wider External Influences On-Site Energy Culture (s)

The focus group and interview also identified various external influences on energy cultures on site, such as organisational culture, business structure and wider governmental priorities. These will now be discussed.

Top-Down Structure, Nature of the Industry, Safety Culture and Government Agendas

The interview with a long-serving staff member (35+ years of employment) provided a valuable insight into the wider organisational culture of the workplace and the site. The workplace being examined has a top-down structure, heavily influenced by the nature of the industry (military and defence), where major decisions are made at an executive board level and filtered through the business. The board priorities fundamentally dictate work tasks and associated energy use.

The interview results highlighted how this staff member noted a change in business culture in the early 2000s, with the evolution of a site safety culture that is engrained in the day-to-day running of the site (as noted by the SQCDP boards). They noted how, in 2004, a new chief executive with previous experience in the petroleum industry with an established good safety culture was appointed. This chief executive regularly walked around sites and questioned safety activities, which had been unheard of before this. During this time, financial incentives, such as safety objectives, were linked to staff bonuses, which, for some senior staff members, could be between 30–50% of their salary. The interviewee commented on how these decisions in the business quickly filtered through the business, and on how safety was discussed during every meeting.

Exploring similarities between safety and energy during the focus group, the researcher asked who the group thought was responsible for reducing energy. Responses centred on the theme of everyone, with participants making it clear that it was currently driven by management. In exploring the contrast with safety, the researcher asked if this differs to safety, and the overwhelming response was energy and safety are different. With answers such as:

> '*Safety's more at a local level*'.

> '*Different issues in different areas, [safety] has to be local, whereas energy use is a site one*'.

Safety is seen as something engrained in daily activities at a local level, while energy is a wider site-related issue.

The interview also highlighted how national government agendas relating to defence spending reviews significantly impact the business agenda. Reflecting on the early 2010s, the interviewee highlighted how cuts in government defence budgets significantly impacted activities relating to energy and sustainability agendas on site:

> '*the funding for us as a energy business just collapsed, so where sustainability was high on the agenda, and we could devote a little bit of money to it, we could no longer. The impact of the defence review was severe and we made a lot of people redundant as a result' (Interview).*

Here the participant not only demonstrates how funding and a defence review directly impacted energy and sustainability agendas but also how it resulted in redundancies, which, as identified earlier, could impact energy cultures on site.

4.5. The Workplace Energy Culture Framework

Revisiting Stephenson et al. [16,17] ECF in light of these findings, it is apparent that the existing framework does not capture the complexity of the energy culture(s) of the workplace and the varying spatial and temporal impacts of wider external influences. Subsequently, this next section of this paper builds on Stephenson's et al.'s [16,17] work and, in taking inspiration from frameworks such as Geels [81], proposes a multi-scalar workplace energy culture that incorporates both the individual energy culture and workplace energy cultures, their characteristics and the wider external influences (Figure 3). In the figure, only a selection of the external influences and characteristics identified from the result have been annotated, for ease of interpretation.

Every employee will have their own distinct energy culture (annotated as 'Individual' in Figure 3) which, as highlighted by Stephenson, et al. [17], can include expected levels of comfort, norms and energy practices that are conducted in other environments such as the home, which may spillover [82] into the work environment, and consequently influence wider workplace energy cultures. Individuals also sit within wider work teams, where an individual's energy culture can contribute to the wider work team energy culture. Some employees, such as managers/supervisors or more senior staff members, e.g., chief executives, and their associated individual energy culture may have a greater influence on a work team's energy culture than other employees.

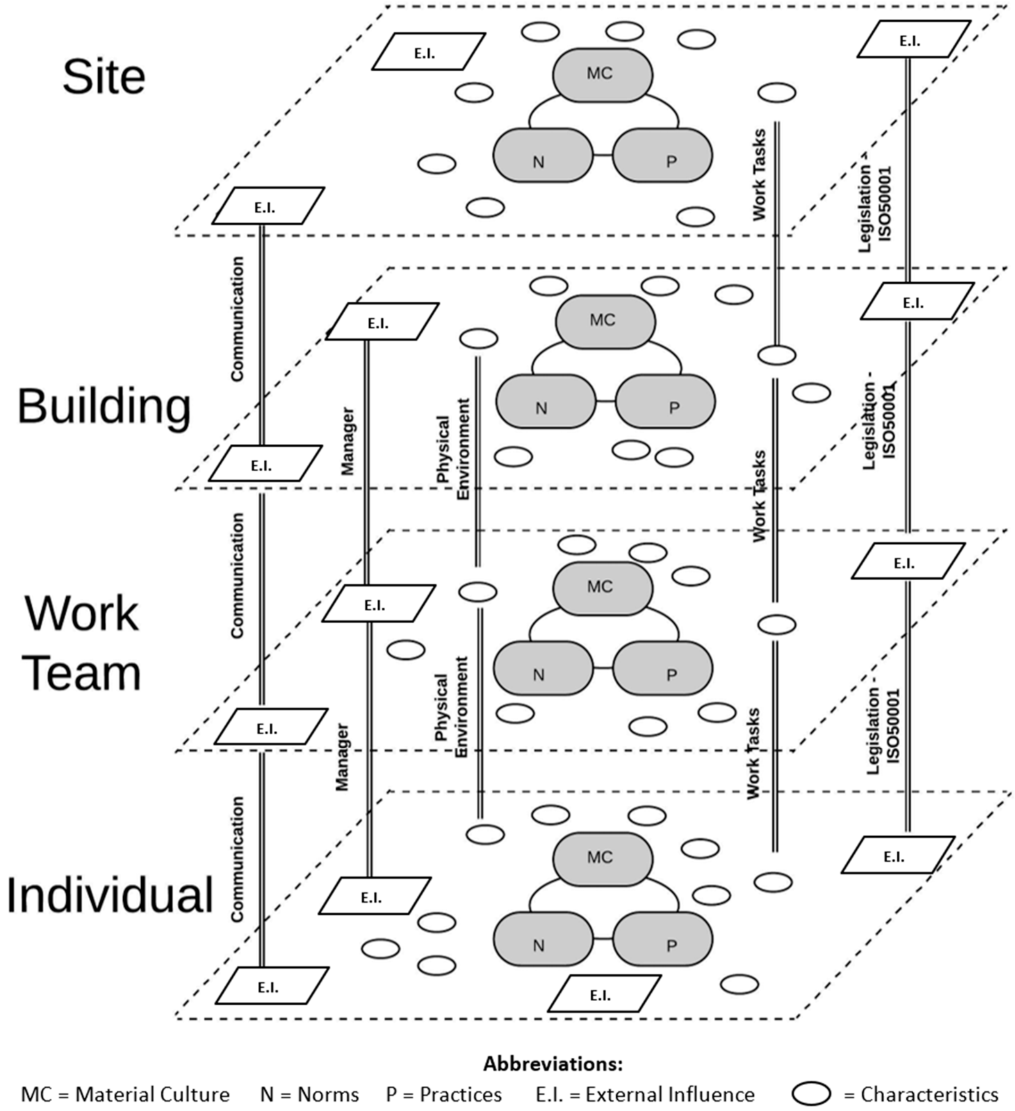

Figure 3. The workplace energy culture framework.

In the workplace examined in this paper, all work teams are situated within specific buildings. The study findings suggest different cultures may exist in different buildings as, for example, in the differences between manufacturing and office environments identified in the survey results or the suggestion, from the focus group, of different cultures existing in different manufacturing buildings on site, due to the level of investment and job security associated with the remaining programme of work. Researcher visits and anecdotal evidence from gatekeepers also suggest that different sites of the broader organisation can also have different energy cultures, suggesting that the site where the research was conducted has a more established energy efficiency energy culture than other sites in the organisation. This concept of there being multiple energy cultures is supported by existing organisational research, which suggests that different subcultures can exist throughout an organisation, and members of each subculture can hold different attitudes towards corporate sustainability [35].

Within each of the scales that energy cultures can be examined (e.g., 'individual', 'work team', 'building', 'site' in Figure 3), similar to Stephenson et al. [17], there are a variety of characteristics and external influences on the energy culture. Some cut through multiple scales, and others are unique to the specific scale being examined. For example, results in this paper suggested the layout of the physical environment is a key characteristic that directly affects energy use, and this is a theme that can be observed within the 'building' (e.g., manufacturing or office), work team (e.g., tasks being conducted) and individual energy cultures (e.g., individual work stations).'Work Tasks' are a characteristic of the energy culture, which spans all the scales, as highlighted in Figure 3. At a 'site' level, this could be defined as the primary purpose of the site, associated with a particular work stream, e.g., maritime, air or land defence; within a 'building', this is the specific process of the wider workstream being conducted including, for example, office-based tasks or manufacturing specific parts for the workstream, and so forth.

Similarly, external influences can span multiple scales. Figure 3 annotates the role of managers, business communication strategies, and external influences, such as legislation that influences energy cultures at varying scales. This paper has identified how a top-down business structure and communication approach assisted in creating an established safety culture. It also detailed how communication methods via email may filter through office areas more effectively than manufacturing areas, demonstrating the influence communication can have on energy culture. In relating to both the established organisational safety culture and communication strategy, this paper also identified how managers impact work tasks. The annotation in Figure 3 identifies managers as affecting the building, work team and individual workplace energy cultures, as detailed by the survey and focus group results that describe how DSUMs and WSUMs are opportunities for managers to inform employees of work tasks and agendas for the day or week ahead. They subsequently impact how energy is used and the energy culture of an area.

The annotations in Figure 3 are intended to demonstrate how some characteristics and external influences will influence energy cultures at different scales in the workplace and may not influence all energy cultures. Additional characteristics and external influences identified in this paper include the impact of colleagues and work teams on 'Work Team' energy culture, the role of government defence budget decisions affecting wider business energy culture (and, subsequently, energy cultures at all scales), and the role of existing wider organisational cultures, such as the 'safety culture' observed on site that is engrained in day-to-day tasks on site.

5. Discussion and Implications

This research applied the ECF [16,17] to a workplace setting to examine if the energy attitudes and behaviours of manufacturing and office environments differ, and to determine if the ECF can be applied to workplace settings to aid understandings of employee energy use and the broader external influences on it. Reviewing the results, this paper found:

(a) *Office and manufacturing employees differ in their attitudes towards energy use, and have different energy cultures.*

The survey findings identified statistically significant differences in the office and manufacturing areas for groups of questions that examined employee attitudes and subjective norms, views on employee energy suggestions and feedback, knowledge of workplace energy reduction practices, employee workplace energy reduction practices, knowledge of business approaches to energy topics, and attitudes towards the role of the workplace SHE function. Applying these findings to the ECF, they suggest the manufacturing and office areas have different energy cultures, with the office areas being more energy efficient. These findings support those of Ucci, et al. [32] who also found differences in office and manufacturing areas, and also found office areas more closely agreed with Likert scale questions on similar themes. It is interesting to note that, in the results presented in this paper, no significant differences were found in groups of questions examining individual concern with energy costs to the business and home energy practices, which suggests that the differences in manufacturing and office energy cultures exist due to workplace constructs, rather than individual drivers.

The differences in office and manufacturing areas are not surprising given that energy efficiency in offices can be a relatively easy task to perform. Generally, office tasks require no specific or advances in knowledge [31]. The equipment and facilities office employees use are similar to equipment often seen in the domestic environment and require, for example, turning monitors or computers off. Additionally in office environments, the consequences of turning the equipment off are low, compared with a manufacturing environment, where turning equipment off could affect production lines.

These results support the claim that employees are not homogenous in their views [12], and workplaces should acknowledge this. Each employee is different; they will have their own energy culture that fits into the wider organisational energy culture, and within this wider energy culture there will be sub-energy cultures, such as those within office and manufacturing areas. This supports work by others (e.g., [43,83]) that suggests employees are part of and apart from the organisations they work in, and the interplay of the organisation and employee is dynamic, with both affecting each other.

(b) *Workplace energy cultures can be examined at different spatial and temporal scales*.

The results assisted in developing the workplace energy culture framework, which visualises the different spatial scales on which energy cultures can be examined in the workplace (Figure 3). Figure 3 highlights the individual, work team, building and site energy cultures identified in the results. It presents a workplace energy culture framework that is a snapshot of the energy culture(s) at the time of research. It is important to note that energy cultures can evolve. Research by Isaksson et al. [25] highlights how the relationships between employees who are drivers and other employees can evolve, and it is anticipated that this changing relationship will influence workplace energy cultures. Additionally, changes to external influences, such as legislation or business approaches, can change workplace energy cultures, and it is anticipated that they will evolve over time.

The concept of energy cultures evolving is not new. In discussing the adoption of energy-efficient technology innovations in buildings, Soorige, et al. [57] propose a culture maturity conceptual framework that provides a holistic view of different energy culture stages, extending from one that obstructs the adoption of energy-efficient technologies to one that supports them. Citing the work of others [84–88], Soorige, et al. [57] highlight that the practice of examining the maturity of cultures is well-established in the workplace when examining topics of safety culture or cultural excellence guides. It is important to note that Soorige et al.'s [57] maturity framework is based on a literature review. However, the results in this paper support their conclusions with qualitative results that suggested: (a) building energy cultures can change with different investments and work contracts; and (b) the safety culture on site has evolved over time with changes in key personnel (e.g., chief executive).

The research findings identified how energy cultures can be affected by internal and external influences. Results identified how the physical environment, work tasks, business investments associated with job security and workloads, and other more established cultures within organisations (e.g., safety culture), can affect energy cultures. These can be categorised as influences that are internal to the business. The research findings also identified several factors external to the business that can affect the energy culture, such as government agendas and legislation. When any of these influences change, the energy culture will evolve.

(c) *There is an interplay of cultures within an organisation*.

The primary focus of this research has been on energy culture topics. However, research findings also identified a dominant 'safety culture' entwined in day-to-day on-site activities. As such, the energy culture in this organisation will be affected by the more dominant safety culture. This finding supports findings by Linnenluecke et al. [35] highlighting how organisations can have several sub-cultures. It is beyond the scope of this paper to discuss the interplay between the safety and energy cultures observed on site. However, researchers and practitioners should acknowledge this interplay of energy cultures with other organisational cultures when examining energy behaviours. Examining existing cultures and how they became established may provide insights into how emerging cultures could become established in different organisations.

6. Conclusions

This research applied the ECF [16,17] to a workplace setting that hosts manufacturing and office-based tasks. The research findings identify that an organisation's energy culture is multi-dimensional, with characteristics and external influences having varied spatial and temporal impacts on workplace energy cultures. The survey results show how office and manufacturing environments differ, with office areas having a much more energy-efficient energy culture. The focus group findings identify several reasons for these differences, including the physical environment, work patterns and activities, and the communication strategy on site. The focus group and interview findings also identified how wider external influences, such as investment decisions, existing more established workplace cultures, business structure and factors outside of the business (e.g., national government defence budgets), could influence how energy is used on site. In light of the research findings, this research proposed the workplace energy culture framework, which builds on the ECF and illustrates the multi-scalar nature of energy cultures, their characteristics, and the external influences in workplace settings.

This work has the following theoretical and practical implications. Firstly, applications of the workplace energy culture framework can aid researchers and practitioners in understanding how energy is used, how energy cultures may differ, and the external influences on energy use. Identifying these will show which factors affect energy culture throughout the business and, thus, which factors could be altered, targeted or prioritised to lead to significant changes in energy cultures and more energy efficiency within businesses. Secondly, this paper identified significant differences in energy cultures within a workplace. There is limited research in this area, and future research is needed to examine these differences further, along with examining different industries. Thirdly, this paper has highlighted the benefits of undertaking a mixed methods approach in settings where the researcher is external to the organisation. The qualitative results provided valuable insight into the energy culture on site and the wider external influences. It is unlikely a solely quantitative approach would have obtained this information. This research supports the calls for more mixed methods and systems thinking approaches to examine workplace energy behaviours [43,55].

Limitations and Areas for Future Research

As with all research, this work has limitations. Firstly, the researcher was an outsider to the organisation, which has benefits, such as providing an unbiased view of the workplace; however, it did mean that to obtain results the research relied on gatekeepers to the organisation. A mixed methods approach was undertaken, and while this reduces any gatekeeper bias, it is possible the researcher obtained a biased view of the business. It is unlikely that this bias could be reduced, due to the nature of this organisation's industry (defence) and the limited access that 'outsiders' to the business can obtain. However, future work that applies a workplace energy culture approach could incorporate other methodologies, such as ethnographic approaches, which could involve situating the research within an organisation and experiencing the energy cultures firsthand. Secondly, the industry associated with the organisation being examined has close military ties and, as such, a traditional top-down hierarchal structure. The findings provide a unique insight into an industry that is under research; however, the findings discussing the energy culture and the external influences are potentially unique to this organisation and site. The external influences are not intended to be a fixed list of external influences but are presented to highlight the variety of external influences at play when examining energy cultures. It is anticipated these will differ for different organisations. Future research could examine the variety of external influences that affect business energy culture, with the aim of creating a resource that researchers and practitioners could use to assist in developing more energy-efficient energy cultures.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su16073072/s1. Table S1: Comments on the PCA suggested grouping of factors (questions) and how they are similar or different to the original questionnaire design themes. Table S2: The PCA groups and the questions included in each group, along with details on how each question was developed including information on whether they were researcher developed, adapted or directly from other sources. Final column of table highlights the original theme that the question was developed to address. ** highlights where a question was originally designed under a slightly different theme. Figure S1: Scree Plot produced from PCA with Varimax Rotation Note: Red lines reflect visual indications produced by the researcher.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Conflicts of Interest: The author declares no conflicts of interest.

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