

*Applying Grounded Theory Methodology with  
Mixed Methods in Occupant Energy Behaviour Research*

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**Abstract**

It has been recognized by many researchers that Occupant Energy Behaviour (OEB), play a vital role in reducing energy use. The previous research into the field of occupants' energy behaviour can be classed into two categories regarding their methodological approaches. The majority of the research has been done using a quantitative approach where conclusions were drawn from monitored energy data along with large questionnaire surveys or tightly structured interviews, in which several factors that relate behaviour to energy use have been identified and agreed upon among researchers (e.g. age, housing characteristics, set point temperature etc.). Whereas only a few studies have adopted a qualitative method, or combined quantitative and qualitative methods. However the findings using qualitative and mixed methods showed potential benefits in gaining a better understanding of sustainability in people's everyday lives and the nature of their energy use, which serves as firmer grounding to march towards energy efficiency. The comparison between these two main research methods in the same field is particularly interesting in terms of discussing the fundamental properties of the subject matter, and discovering specific aspects of energy behaviour which these different approaches could bring to the field. This paper reviews research from last decade regarding occupants' energy behaviour, focusing particularly on studies of residential low-energy buildings and Passivhaus, and compares the above three types of methodologies with a quantitative and qualitative methods, then tries to make a case for mixed methods with an emphasis on Grounded theory in this research field.

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## **1. Introduction**

Energy behaviour and sustainability research has been a highly-mixed interdisciplinary field. The publications regarding this topic can be found in various research subjects including energy policy, psychology, engineering, architecture, economy, marketing and computer science, etc. The property of this subject matter makes its research paradigm hard to follow, and it also adds up to the difficulties in evaluating previous research findings and methodologies. This article examines the suitability of different types of methodology for an on-going PhD research on Passivhaus and occupant energy behaviour. The first part of the article will briefly review the development of research methodologies and their roots in epistemology, the second part will review and analyse the methodology used in energy behaviour research since the past two decades with a mixed quantitative and qualitative method, to reflect the pros and cons and suitability of each type method introduced in the first part. The third part will introduce Grounded theory as an appropriate methodology candidate in conducting OEB research and will discuss ways to combine quantitative methods into Grounded theory methodology.

## **2. Research Paradigm**

### **2.1 From Epistemology to Method**

Dainty (2008) suggested that, ‘...research methods cannot be viewed in isolation from the ontological and epistemological position adopted by the researchers.’ According to Crotty (1998) there are four major steps to rationalize a research philosophy with research method (Fig.1). The epistemology of the researcher which deals with ‘the nature of knowledge, its possibility, scope and general basis’(Crotty, 1998) towards the subject matter determines appropriate research approach, and the methodological approach should fit in the conceptual framework of epistemology. The epistemological position most researchers adopt can be classified into two distinctive categories – Positivism and Constructionism. Positivist epistemology tends ‘to make time and context free generalizations’ and ‘to believe this is possible because human actions can be explained as a result of real causes that precedes their behaviours’ (Carson, 2001), while constructionist epistemology argues ‘social phenomena are produced through social interaction and are therefore in a constant state of revision.’ (Dainty, 2008). It has been commonly regarded that these two types of epistemology have laid the philosophical foundation towards research methods, in which quantitative methods are best suited for positivism while qualitative approach is appropriate for constructionism exclusively. However, to conduct a research question-centric study, as Crotty (1998) pointed out, ‘...it is a matter of positivism vs non-positivism, not a matter of quantitative vs qualitative.’ Therefore, many researchers argue that it is possible to conduct a research orientated by qualitative method within the boundary of Positivism research or to use quantitative method in a fundamentally Constructionism - grounded research.

Figure 1

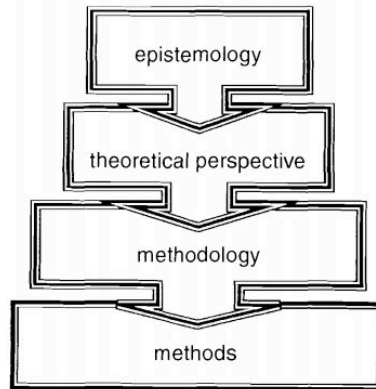


Fig. 1 Four elements of research design. Source: (Crotty, 1998)

## **2.2 Quantitative or Qualitative – research paradigm shift in social and behavioural sciences**

The occupant energy behaviour research grounded its root in the field of social and behavioural sciences, thus it is essential to look back into the methodological development in this field to understand the philosophy behind the subject matter. Lund(2012) suggested in his article that, since the last 50 years, the research methodology in social and behavioural sciences had gone through three major research paradigm shift, namely quantitative movement, which dominated first half of 20<sup>th</sup> century; qualitative movement that became popular in the 70s and mixed methods movement, established itself in the beginning of 21<sup>st</sup> century. (Tashakkori and Teddlie, 2003), In between the transformation was the so-called ‘paradigm war’ (Gage, 1989), where ‘philosophical basis, scientific fruitfulness, and empirical methods [of the two polar research methodologies] have been extensively debated’ (Lund, 2012), along with the discussion of the compatibility to combine the two methods into one research framework. Also in his article, a thorough analysis of 1,958 cases of social and behavioural research during the past decade has been done and a trend of using mixed methods is noticeable however the mixed approach is still under-developed.

Indeed quantitative and qualitative research methodology are fundamentally different and need different execution process, however previous research argues that ‘the use of mixed methods can enrich and improve our understanding of the matters under study... in order to give answers to questions that are difficult to answer by a sole classical method.’ (Lund, 2012). Considering the high priority given to empirical research questions, it is possible to design research methodology accordingly and make a combination of the two types of methodologies to serve the purpose of answering the specific question. Researchers have summarized five main reasons to adopt mixed research methodology. They are triangulation, complementarity, development, initiation, and expansion (Hesse-Biber, 2010).

## **3. Research methodology review in occupant energy behaviour research**

### **3.1 Methodology**

Following the methodological analysis in the field of social and behavioural science, a more specific and closer examination has been undertaken into the field of occupant energy behaviour research. A literature review on research methodology has been conducted, the methodology used here is a mixed approach, using sequential equal

weighted quantitative and qualitative methods. The data were drawn from previous research in EBSCO database. To eliminate the deviations in keywords and to reduce irrelevant research articles to a minimum, the search was set up for keyword search in abstract (AB) mode for both ‘occupant energy behaviour’ and ‘user energy behaviour’. The decision of timeframe of 10 years was partly because that mixed method has been hugely promoted after the publish of Tashakkori and Teddlie’s Handbook of Mixed Methods in 2003 (Lopez-Fernandez and Molina-Azorin, 2011), it is also due to the limited access to articles before 2004 online in terms of the relevant topic. The data scope was determined within four major peer-reviewed journals in built environment and energy, they were also top four journals that contain the most relevant articles on the result of keywords search. They are ‘Energy and Buildings’, ‘Energy Policy’, ‘Building Research and Information’, and ‘Building and Environment’.

The first stage uses quantitative method to categorize research methods used in these journal articles to determine pattern and trend of research methodology in the field. The second stage uses qualitative method to analyse the characteristics of selected research that adopted respectively quantitative, qualitative and mixed methods to make comparison.

### 3.2 Quantitative Analysis

Keyword search in EBSCO database came back with 122 hits. Preliminary examination eliminated another 22 duplicated or irrelevant articles, leaving 100 in total. The ‘Quantitative’ category here refers to research with quantitative methods, including questionnaire survey, data monitoring, computer simulation using quantitative data, case study using questionnaire survey etc. ‘Qualitative’ category includes only qualitative methods such as interview, observation, diary, etc. The ‘Mixed’ category refers to research using both quantitative methods and qualitative ones, this also includes several case studies that fit the criteria.

As can be seen from the following table, the majority of the research uses a quantitative approach.

Research using purely qualitative method is very rare - only three cases recorded in one journal. Similarly, mixed methods are also in lack of use – only eight cases in two journals.

	Quantitative	Qualitative	Mixed	Non-empirical	Total
Energy and Buildings	52	0	0	0	52
Energy Policy	8	3	3	2	16
Building Research and Information	9	0	5	1	15
Building and Environment	17	0	0	0	17
Total	86	3	8	3	100

Table 1. Quantitative analysis of previous research on occupant energy behaviour

### 3.3 Qualitative analysis

Many researchers have agreed that the use of mixed methods can be classed into four different types, in terms of research procedure and in terms of weighting (Creswell, 2003, Bryman, 2012, Morse, 1991):

(a) *Equal weight, simultaneous: (1) QUAL+QUAN.*

(b) *Equal weight, sequential: (2) QUAL → QUAN; (3) QUAN → QUAL.*

(c) *Different weight, simultaneous: (4) QUAL+quan; (5) QUAN+qual.*

(d) *Different weight, sequential: (6) qual → QUAN; (7) QUAL → quan; (8) quan → QUAL; (9) QUAN → qual. (Lopez-Fernandez and Molina-Azorin, 2011)*

Following the categorization of mixed methods design, the previous 8 research cases can be further analysed as follows:

Year Published	Notation	Summary
2010	QUAN → qual + QUAN	Quantitative dominant sequential mixed methods, qualitative interviews were used as supplementary to quantitative questionnaires and a way to handover for next research stage
2011	QUAN + qual	Semi-structured interview were conducted to explain behaviour differences to monitored data
2011	QUAL + QUAN	This research has two parts, part one is case study with a selection of 6 cases, part two is internet based questionnaire survey, they were discussed in an equal manner, although conducted in different times but they didn't have any sequential relationship
2013	QUAL → quan → QUAL	This research uses data from interviews and field monitoring. Two sets of interviews were conducted sequentially, quantitative monitored data was used as a link.
2010	QUAN → qual	This research involved a bespoke questionnaire survey supplemented by qualitative interviews, along with monitored energy use.
2010	QUAN + QUAL	Various methods to monitor data, diary logs, graphics and interviews were used in qualitative part
2010	QUAN + QUAL	
2010	QUAN + QUAL	
		Data monitoring and interview with occupants

Table 2. Qualitative analysis of previous research on occupant energy behaviour

This analysis of research procedure and weighting in mixed method research has proved to be consistent with the general result where the field is dominated by quantitative research. However, in mixed methods, it appears to have more research done with quantitative and qualitative equally weighted than emphasizing predominantly on one method. On the other hand however, the publication time of all articles using mixed methods are dated after 2009, which showed an increase compared with 5 years ago.

To take a closer look at some particular research, De Meester's case study (2013) into 11 buildings with controlled building characteristics quite satisfyingly examined empirical studies of OEB in relation to insulation levels, as a theory testing method, it is successful in controlling parameters and drawing valid comparisons. Santin's data (2011) was originally collected by KWR of the ministry of Housing of the Netherlands on 15,000 houses, the survey was structured interview-based, carried out randomly along with another set of 3 years' energy data from energy providers. This was a good combination of data sources to study energy behaviour, however, as the author suggested himself, the data was obtained from 9 years previously, but the analysis didn't take energy price growth or other development into account, and variables were categorical values and only relevant to one or two categories. This has in a way suggested that quantitative research is lack of depth to consider deeper connections of ideology and phenomenon. Likewise, Blight and Coley's research (2013) used a third party tool on a survey of 20,000 weekly UK household journals to measure data from *Passivhaus* around central Europe using a computer model. It is a growing trend to use simulation in energy research, but it is arguable that this is not based on real life scenarios when behaviour data gathered was not from actual *Passivhaus* users to test theory. Stevenson (2013) examined technological control usability using surveys with both closed questions and optional open-ended questions where occupants could express their opinions more freely in order to discover design problems. As an example of qualitative analysis, Gyberg et. al (2009) studied information from energy advice website and conducted participant observation of energy meeting to learn how various actors (companies and government) advise Swedish households to reduce energy use and the effectiveness of their effort. This study used discourse analysis, which 'is a way to structure a text to discuss what issues the information highlight and on what assumption the advice is built upon' (Per Gyberg, 2009). This research suggested that current energy reduction programme targeted more on consumer options in terms of energy efficient products instead of needs for consumption thus not very efficient. From a methodological point of view, this inductive research uncovered a theory that can hardly be defined by quantitative research. In mixed approach research, both Stevenson (2010) and Rajat (2010) advocated mixed approach in developing an occupant feedback and evaluation system, which includes performance factors such as U-value, energy use, but also quality of life and comfort that can be documented through diaries, videos and conversations, etc. Equal weighted, simultaneous mixed research is considered as appropriate to serve the purpose. Risholt (2013) conducted a qualitative-focused mixed approach using interview and observation methods as a follow-up study to a quantitative research on Norwegian housing. The cases were selected based on the previous quantitative analysis, the interviews were triangulated with previously recorded energy use data, and reviewed deeper understanding of the situation of sustainable renovation such as lack of knowledge, bad advices from craftsman etc. Likewise, Coleman (Coleman et al., 2013) conducted two-stage interviews with energy data collection in between as sampling selection to study the effectiveness of energy feedback system.

#### **4. Suitability of mixed methods in Grounded theory**

Despite the popularity of Grounded Theory in social and behavioural research, this methodology was rarely recorded in any occupant energy behaviour research from the past 10 years. It is understandable given the dominant position of quantitative research in this field. However, considering the advantages and disadvantages in

previous research methods, a mixed approach is proposed, with application of Grounded theory methodology. Grounded theory 'is one that is inductively derived from the study of the phenomenon it represents. That is, it is discovered, developed, and provisionally verified through systematic data collection and analysis of data pertaining to that phenomenon.' (Strauss and Corbin, 1990). Strauss and Corbin inconsistently referred to grounded theory as 'method' and 'methodology' in their book, however, under the analysis of Crotty (1998), grounded theory will be discussed as a methodology here. It has been used extensively in Sociological and Psychological studies of behaviours and experiences, but very rarely in the field of Architecture and Built environment. By applying grounded theory in collecting and analysing occupants' behaviours and experiences in a social context, it allows relevant themes to emerge not only from the field of built environment but from a holistic range of domain. The theory to be generated will meet four central criteria that are termed 'fit, understanding, generality, and control.' (Glaser and Strauss, 1967), it will be comprehensible to occupants and clients as well as building professionals.

The features of grounded theory that made it appropriate for this research are as follows;

Firstly, Grounded theory can make a great contribution to the field that is relatively new, or bring a fresh viewpoint to areas where extensive research has already been done.

As stated previously, research into the field of OEB is not exactly new, however with regard to *Passivhaus*, the behaviour of occupants is influenced by innovative technologies and novel ways of interacting with the house. Ideas about occupant comfort need to be reconsidered in light of this, as the old model may be insufficient to fully describe behaviour in a *Passivhaus* environment.

Secondly, it provides connections with broader contextual issues to the phenomenon and thus builds up a thorough framework from microscopic details that were previously being neglected. To study the social side of each households and their ideology in purchasing/building, operating, revising the low-energy housing, a qualitative approach is appropriate to engage a more complete picture of the comparison between occupants.

Thirdly, Grounded theory involves theory development (Denzin and Lincoln, 2000), and is unique in a way that it has a concurrent approach in both collecting and analysing data. Therefore, the data analysis in the research process will be taken at the same time as data collection, to ensure that the area of interest and the method suit each other (Knight and Ruddock, 2008). This allows researchers to have an open-ended conceptual framework and supplement relevant aspects/concepts as the data collection progresses until no further information emerges to generate a theory. As the central framework unfolds, both technical literature and data collection started to contribute in more and wider aspects of the frame. It is highly appropriate to explore the social side of such a phenomenon as comprehensively and completely as possible, and to uncover themes that were neglected in previous research.

It is commonly believed that quantitative methodology is essentially a deductive methodology most suitable for theory testing while on the other hand qualitative

methodology is an inductive process for theory generation. In the framework of grounded theory, where ‘the concepts and relationships among them are not only generated but they are also provisionally tested’ (Strauss and Corbin, 1990), it has naturally provided a ground for quantitative and qualitative methods to work together.

## 5. Applying quantitative methods onto Grounded theory

The following will give brief introduction to Grounded theory methodology and its application process, in order to discuss the feasibility in theory to combine it with other quantitative methods in OEB research, and if the two polar will complement each other.

Grounded theory features three main application procedures.

Firstly, open coding, the process of open coding is to get as much relevant information on the focused field as possible to determine categories as a base for further approaches. This needs to be a continuous process throughout the whole research until it reaches **Theoretical saturation**. *This means 1) no new or relevant data seem to emerge regarding a category, 2) the category development is dense, insofar as all of the paradigm elements are accounted for, along with variation and process, 3) the relationships between categories are well established and validated.* (Strauss and Corbin, 1990) Data in open coding is collected by indiscriminate, unstructured sampling and semi-structured interviews and observations, to make sure the data is grounded. However, to know if theoretical saturation is reached, one best way to test is by questionnaire survey aiming to reach as many people as possible in quantity to learn if there is new yet undocumented category. Also, carefully structured questionnaires with open-ended questions will help uncovering new categories even with quantitative approach.

Secondly, Axial coding. It is based on the result of open coding, which will put data back together, and ‘making connections between categories by utilizing a coding paradigm involving conditions, context, action/interactional strategies and consequences’. (Strauss and Corbin, 1990). This step allows a connected image to be presented within categories to form a basic story line of cause and effect, and detailed study of each category and its subcategories to a measurable degree. To enable Axial coding, **Relational/Variational sampling** – ‘*Relate categories in terms of the paradigm, focuses on uncovering and validating those relationships.*’ (Strauss and Corbin, 1990) This is a formation process of hypotheses, it needs to be proceeded deductively. In Axial coding, deductive process will be involved more in data analysis to generate possible hypotheses. To test these hypotheses by varying dimensions of properties, quantitative approach will provide a more efficient and effective way.

Finally, selective coding. The purpose of this step is to select ‘the core category, systematically relating it to other categories, validating those relationships, and filling in categories that need further refinement and development’. (Strauss and Corbin, 1990). As a qualitative approach, this step will involve researcher’s interpretation more as a selective process in determining a core storyline of the research, it needs to be carefully examined in tandem with the two previous steps. Selective coding needs to be verified and tested by **Discriminate Sampling**- ‘*chooses the sites, persons, and documents that will maximize opportunities for verifying the story line, relationships*



*between categories, and for filling in poorly developed categories*. (Strauss and Corbin, 1990) That is to test the hypotheses in order to generate a theory.

Each of the three procedures need to be tested for verification, the data collection for each procedure becomes two-part process, quantitative approach can be integrated sequentially after qualitative method to test hypotheses, meanwhile, quantitative questionnaire survey can also be used as an initial step to select participants to conduct interview and uncover more research dimensions (new categories in grounded theory), then followed by another round of qualitative interviews.

## 6. Research design

For Grounded theory method alone, at least three separate sets of data need to be collected throughout the process. They can be the same group of targets or different ones, but all the three stages of open sampling, relational sampling and discriminate sampling have to be built into data collection. As it proceeds, generated hypotheses need to be tested in the interview along with open coding process, and it is appropriate to look back and re-examine a former data in relational or discriminate sampling. The data collection process therefore embodies collection, analysis, and testing. As stated above, to mix quantitative method with Grounded theory in this case, quantitative method is mainly for testing.

On the other hand, as an alternative way to combine the two methods, interview and questionnaire survey can be conducted simultaneously, in order to understand the phenomenon in a narrative way and in this particular case, uncover problems that cannot be simply observed using one type of method alone. The following diagram demonstrates how mixed methods can be combined into Grounded theory framework. The ongoing research project will try to apply such methodology.

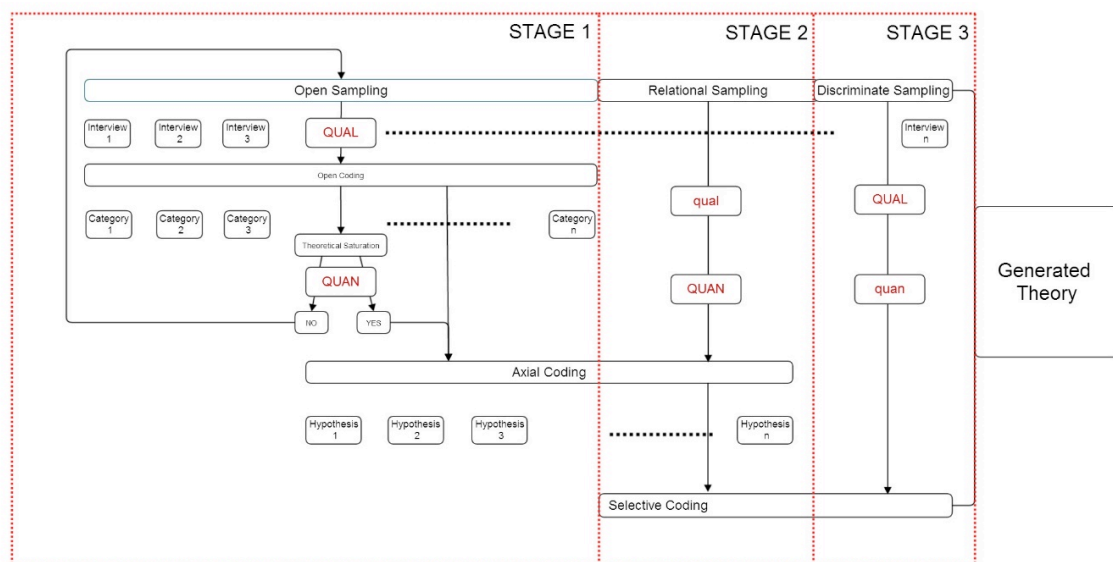


Fig. 2 Mixed methods in Grounded theory framework

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