

# **Evolutionary, not revolutionary – logics of early design energy modelling adoption in UK architecture practice**

## **Abstract**

This paper examines the effects of early stage design energy modelling technology on architects' design practice. Energy analysis in design has traditionally been the domain of the building services engineer with emphasis placed on verifying established building simulation models at late stages in design. Recently, however, with advances in digital design media, leading architectural firms are acquiring in-house design simulation for energy modelling. The effects of broadening the use of energy modelling technology on architecture design practice or the design process are however, poorly understood. Industry and academic attention has been gathering on the topic of building performance simulation with most of the focus placed on standardising the wide array of tools and narrowing the broad spectrum of analysis parameters. Few discussions examine approaches to energy analysis across the diverse design settings and the principles, assumptions and identities designers negotiate. The analysis draws on institutional theory utilising semi structured interviews and focus group sessions with 26 participants across 4 large international architecture firms. Preliminary findings indicate differing organizational, team and project approaches with an emphasis placed on legitimating established design assumptions across the firms. The implications of the findings are twofold. First, the analysis provides an initial overview of how early stage design energy modelling is considered in design in architecture practice in the UK. Second, the paper provides an understanding of how architects negotiate meaning on energy in design. There are also implications for energy policy development in the context of the built environment particularly concerning building performance.

**Keywords – architecture, building performance, design practice, energy modelling institutional logics**

## **Introduction**

Energy analysis in architecture has traditionally been the domain of the building services engineer with emphasis often placed on verifying established simulation models at late stages in design. Recently, however, with advances in digital design technology, new simulation tools and policy initiatives in the UK such as the Carbon Buzz<sup>1</sup>, uptake of early design energy modelling tools has been growing amongst other design professions in particular architects (Weytjens and Verbeeck 2010). The growing agenda on energy modelling use in architecture is also evident internationally. Recent guidance developed by the American Institute of Architects (AIA) argues for greater engagement from the architecture profession in the USA to better integrate energy modelling processes within their design practice (AIA 2012). The effects of broadening the use of energy modelling technology on architects' design practice are, however, largely unexamined and poorly understood.

---

<sup>1</sup> Carbon Buzz is a Royal Institute of British Architects (RIBA) and the Chartered Institution of Building Services Engineers (CIBSE) online platform platform that benchmarks and tracks building project energy use from design to operation.

Research has been suggesting for some time the difficulties building design professionals encounter with the growing complexity of interfaces, energy design tools and analysis parameters (Oxman 2008). Technical comparisons of energy modelling tool features (Crawley et al. 2008) as well as surveys carried out with building design professionals (Attia et al. 2012) suggest there are difficulties in accessing tools and interpreting diverse results. In addition, studies have suggested growing concerns in the building design community as to whether tools accurately predict building performance (Negendahl 2015, Oreszczyn and Lowe 2010). Most studies tend to emphasize the need to standardize and narrow the broad spectrum of analysis parameters (Hensen and Lamberts 2012).

The current focus of discussions in building energy modelling scholarship is on improving the technical accuracy of modelling tools particularly to address the ‘performance gap’ (De Wilde 2014). The emphasis placed on enhancing tool features has overshadowed and limited exploration into the social implications modelling technology has on both the design process and different design professionals’ conceptions of energy. An analysis into architects’ use and effect of energy modelling technology is crucial to enabling a deeper richer understanding of designing for an energy efficient built environment.

The gap in the research is explored by focusing on the effects of early stage design energy modelling technology on architects’ design practice. The purpose of the paper is to examine how architects negotiate the adoption of innovative energy modelling tools, in particular *Sefaira*<sup>2</sup> in their design practice. To explore this question, the analysis draws on the theoretical lens of institutional logics. An institutional logics perspective is helpful as it views approaches to technology negotiation as enacted through the social context within which users are situated (Thornton et al 2005). The following sections review the literature on energy modelling in building design, followed by a discussion of the institutional logics theoretical framework. The subsequent sections reflect upon the research methods, findings and conclude by highlighting key implications and areas for further research.

### ***Background on energy modelling in building design***

Energy modelling of buildings has received increasing academic, policy and practitioner attention over the past decade. Whilst policy and practitioner discussions have focused on providing guidance and encouraging broader use (Sullivan 2012, Beagle et al 2014), academic discussions have largely focused on improving current modelling tools. Distinct streams of academic research emphasize analyzing approaches to understanding buildings’ energy performance whether entailing prediction, assessment and/or management.

---

<sup>2</sup> Sefaira offers the industry’s only software for real-time Performance-Based Design. Following the release of their real time analysis plugin for SketchUp in November, Sefaira helps integrate energy analysis and performance visualization into the digital design workflow (USGBC 2015).

Discussions on energy performance prediction offer helpful insights into the technical aspects and capabilities of various modelling tools. A dominant strand of discussions emphasize the need to improve current approaches through redesigning existing tools (Dong et al. 2014) or standardizing current methods through new integrated data bases (Coakley et al. 2014). Most recently, concerns are focused on resolving the ‘performance gap’ and addressing inaccuracies between predicted and actual energy use (de Wilde 2014).

A number of recent literature reviews point to a need for cohesion between the multiple approaches whether related to prediction, assessment or management of building energy performance (Chung 2011, Fumo 2014, Li and Wen 2014). Fumo (2014) for instance, highlights the need for an up-to-date review that takes account of the “basics of building energy estimation”. His review collates various models developed for whole building simulation and suggests a classification system is required. Li and Wen (2014) similarly provide a summary on the application of building energy modelling methods in optimal control for a single building and multiple buildings. Different model-based and model-free optimization methods for building energy system operations are reviewed and compared technically.

Coakley et al (2014) compare and contrast deficiencies and benefits of some of the technical features of a wide range of modelling tools. De Wilde (2014) reviews approaches to examining the performance gap between predicted and measured energy performance. He identifies three types of gap, and suggests a reduction in the performance gap could be achieved through a number of measures. These measures include enabling a combinative approach that incorporates validation and verification, improved data collection for predictions, better forecasting and change of industry practice (De Wilde, 2014). Crawley et al. (2008) review a report, which compares and contrasts 20 energy simulation programs in terms of their features and capabilities, and identify the benefits and challenges of these programs. Zhao and Magoules (2012) similarly review the applicability of recent developments in simulation models, and suggest further improvement is required to better predict energy consumption in buildings. Most studies emphasise the need for the development of a template, standard or protocol as a way of standardizing current approaches.

Another stream of discussion focuses on reframing how modelling is used at different building scales or in site-specific problems or situations. Anderson et al (2015) propose a new analysis framework that accounts for both urban and building scales viewed as a critical approach to achieve environmental objectives currently analysed at separate scales. Pisello et al (2012) suggest modelling techniques need to not only be specific to a building but also take account of larger urban contexts. They conduct a simulation exercise which takes account of the urban context revealing that buildings “can mutually impact the energy dynamics of other buildings and that this effect varies by climatological context and by season” (37). Ham and Golparvar-Fard (2013) suggest new methodologies based on collecting actual energy data. They test and “validate” their model on what are seen as typical ‘residential and instructional buildings’.

Scholarship that focuses on the generation of new tools highlights the need for a change in the way in which tools are configured. Crawley (2008) argues that building

energy performance simulation tools have the capability to evaluate a wide range of responses to external stimulus and could be developed to allow for overheating prediction as well as broader evaluation of alternative technologies. Korolija (2011) proposes the development of a regression model based tool that enables the selection of HVAC systems for office buildings. Similarly, Harrington (2001) suggests the generation of a new tool that incorporates annual building energy simulation.

Whilst many discussions suggest that improving current features would offer solutions, other scholars emphasize the need to reframe and simplify current methods. Early work by Tucker (2004) proposes a simplified method whereby considerations of energy and environment can be integrated into each project from the very start of the design process. Balcomb (1992) suggests building simulation tools need to be user friendly and also produce effective results quickly in order to be useful in building design. Hobbs et al (2003) argue that a broader adoption of energy modelling depends on team contractual and working arrangements, suggesting a need for greater experimentation and collaboration amongst design professionals. More recently Bleil de Souza and Tucker (2015) suggest that the development of tools needs to be informed by users. Their custom based framework is argued to allow software developers flexibility in approach often hindered by statistical analysis.

Debates generally focus on ways to enable accurate prediction in either proposing the development of new models, improved techniques, simplification or application of additional data. Scholarship that emphasizes the investigation of energy performance prediction rarely discusses how the use of particular simulation tools and models influences certain aspects of the design process. Also, few studies question or critique the effect modelling technology has on a design professional's understanding of energy performance in relation to other design parameters. Instead, energy performance prediction is largely discussed in isolation of other social, design or organizational issues.

### ***Architects' use of energy modelling technology***

Traditionally energy modelling technology and architectural design have been viewed as separate design activities. According to Hetherington et al (2011) the architectural design approach is guided by a view of a building as composed of objects, whilst an energy modelling view is that of a building comprised of thermal zones. Others approach the historical separation of activities as an opportunity for architects (Sullivan 2012). Tupper et al. (2011) call for a deployment of energy modelling use by diverse users particularly architects. Their study suggests that a diversification in the use of the technology could enable a broader array of decisions (Tupper et al. 2011). Although there are few empirical accounts of architects' use of energy modelling technology, recent studies begin to account for how leading firms develop knowledge on types and range of tool parameters (Zapata-Lancaster and Tweed 2016, Naboni 2013, Mahdavi 2013, Weytjens and Verbeeck 2010).

Zapata-Lancaster and Tweed (2016) draw on an ethnographic study of architecture firms in England and Wales to examine how modeling tools such as IES and TAS are experienced by design professionals. They suggest designers tend to

initially rely on experiential knowledge rather than simulation tools, viewed mainly as validation mechanisms rather than exploration tools. General site conditions and constraints as well as the building potential tend to be explored initially during early stages of design with modelling viewed as a way to evidence achievement of targets. Soebarto et al (2015) conduct surveys with architecture firms in the USA, UK, Australia and India finding that in most cases architects recognized the importance of early stage energy modelling, however, largely did not implement it in their design practice. According to Soebarto et al (2015) most architects did not view energy modelling as their responsibility, viewing all the technological advancements on energy modelling as largely outwith their domain and the responsibility of other experts. Their study suggests greater emphasis needs to be placed on energy performance within architecture education and professional development of architects.

Naboni (2013) maps key modelling tools promoted by leading architecture practices. His study identifies two main categories of ways in which modelling technology is promoted by large international architecture firms. The first category is described as ‘semi-digital designs’ perceived to be developed “according to the architect’s knowledge of sustainability, experience and sensitivity to climatic contexts and human factors” (Naboni 2013, 5). The second category ‘fully digital designs’ are argued to be “driven by environmental data” (Naboni 2013, 5). In a similar study Weytjens and Verbeeck (2010) review six energy modelling tools including Ecotect, IES/VE – Sketch-Up, Energy10, eQuest, HEED, and Design Builder highlighting the level of user-friendliness to architecture practice. According to Weytjens and Verbeeck (2010) most of the tools reviewed did not show adequate applicability of ease and user friendliness in most architects’ design decision-making processes. Their study concludes that the main limitations of tool features relate to poor communication and visualization of the output results.

For some leading practices, use of energy modelling technology is argued to bring about new internal working arrangements and structures as well as new design methods. Mahdavi (2011) highlights architects’ skepticism towards the potential of energy modelling to support decision making as well as lack of practical simulation ‘know-how’. In addition, his study reflects upon the perceived disconnect between the simulation process and the architectural design process.

Other scholars have tended to focus on strategies to enable greater and more user friendly adoption such as developing new frameworks of workflow. Negendahl et al (2015) propose a new approach that takes account of whole building energy ‘agent – based’ optimization applied in the early design stage. Their study suggests that agent-based optimization algorithms allow for user intervention during optimisation. Østergård et al (2016) also propose a new simulation framework that enables proactive intelligent decision making in early design stages. Lin and Gerber (2014) propose a multi-disciplinary design optimization framework that provides more fluid feedback to architects. Their study tests the applicability and usability of the framework through a series of experiments suggesting the use of performance barriers is required.

Whilst Negendahl et al (2015) and Lin and Gerber (2014) focus on providing approaches that enable user friendly interfaces with early stage energy modelling,

Grinberg and Rendek (2013) suggest workflow mapping in a BIM environment is needed. Their suggested workflow map draws on twelve parameters argued to enable better communication and improve decision making early in design. According to the mapping, practitioners are able to identify points in the schedule where modelling activities, budgets and design workflows clash. Shi and Yang (2013) argue a reconfiguration of conventional architectural approaches that emphasize spatial experience, aesthetics and form is required. Their study suggests a performance driven approach needs to develop in order to extend current conventional practices.

Most research analyzing architects' approaches to energy modelling does not rely on qualitative empirical data, basing discussion on objective reviews and comparison of tool features. In addition, there is a paucity of theoretical discussion or consideration, viewing technology and tools largely through an objective technical lens. The following section outlines the theoretical framing of this study reflecting upon the value of an institutional logics approach to exploring use of energy modelling in architects' design practice.

### **Theoretical Framework**

Institutional theory is a helpful theoretical lens well suited for studying approaches across and within organizations (Thornton et al. 2005). As diverse organizations undergo ongoing rapid technological change, researchers draw on concepts of structuration, innovation, and emergence to understand how users experience technology in use. With a similar purpose, this study draws on institutional theory as a theoretical lens to examine how users interact with new technologies and the logics they draw on to negotiate particular views. Organizations comprise of a variety of user groups that often have different goals and assumptions, and draw upon different organizing principles, identities and assumptions ("logics") for appropriate practice. The concept of institutional logics enables a contextualization of users' engagement with technology within organizational and societal institutions (Friedland 2012).

Institutional logics are defined as "organizing principles that govern the selection of technologies, define what kinds of actors are authorized to make claims, shape and constrain the behavioral possibilities of actors, and specify criteria of effectiveness and efficiency" (Lounsbury et al. 2002). The concept of institutional logics enables the analysis of broader institutions' link (at the organizational and societal levels) to individual practices (Berente and Yoo 2012; Friedland and Alford 1991).

Initially logics were mainly seen to occur at societal levels. Friedland and Alford (1991) argued that societal context and, more significantly, society moderated the decisions, actions and behaviours of actors at multiple levels. From that initial conception of logics as societal orders at family, religion, or market levels, recent research has developed views of logics examined at professional (Dunn and Jones 2010) and industry levels (Thornton and Ocasio 1999). Organizations can be institutionally plural, and individuals can draw on different—sometimes consistent and sometimes contradictory—institutional logics (Kraatz and Block 2008).

Most studies on technology adoption in institutional research have tended to focus on how major technological change occurs and the role particular organizations or events play (Boland et al 2007; Berente and Yoo 2012; Yoo et al 2006). Although institutional logics research on use of technology in architecture contexts is limited, there is a developing interest in digital practice in related design domains. In their study on the use of CATIA, a computer-aided design tool commonly used for aerospace applications, Yoo et al (2006) examine how architecture practice Frank Gehry, approached using the tool differently with various suppliers across four projects. Similar aspects of CATIA resulted in different practices depending on the institutional logics that guided the action.

Tumbas et al (2015) study informs research on digital innovation, and emphasizes that organizational actors make sense of technologies in their local context. Their study compares how three different industries including car, web and architecture organizations implement new digital technologies. They draw on institutional logics' characteristics viewed to contain organizing principles, assumptions, identities and domain of application in order to identify variations between the cases as illustrated in Table 1. Within the architecture organization they identified a *Logic of software based projection drawing* characterized by principles of 'delivering unique artifacts'. When studying the car manufacturing organization, they found a similar logic was characterized by principles of 'achieving rapid innovation'. Their study concludes by suggesting that actors trigger organizational change by combining distinct practices from various institutional logics and incorporating them into their own profession.

<< Insert Table 1 here >>

'Principles' characterize logics as activities that embody goals and values of an organization, whilst assumptions embody understanding how a goal can be achieved. Identities on the other hand relate to the enactment of particular beliefs whilst 'domain of application' defines the context of the particular activity or set of activities.

### **Research methods**

The research adopts a qualitative multiple case comparative analysis design in order to explore how actors in different settings approach a similar issue. In the comparison of the cases the main unit of analysis is 'evaluation of energy modelling' rather than the organizations observed (Ragin 1989). The research for this study relies on four case studies represented by large UK architecture firms: Studio 'A', Studio 'B', Studio 'C' and Studio 'D' (see Table 2).

<< Insert Table 2 here >>

The cases were selected as they were all in the process of recent implementation of an early stage energy modelling tool Sefaira across their projects. In addition, all firms were of a similar size and had multiple office locations across the UK. According to the United States Green Building Council (USGBC) Sefaira offers ‘computer simulation of building energy use given a description of its architecture, lighting and mechanical systems, occupancy and use, and local weather— is a powerful tool for architects and mechanical engineers<sup>3</sup>.’ Although used in the US since 2010, application in UK architecture firms has been more recent. The interest in Sefaira in particular has been as it is viewed in industry discussions as a leading innovation in energy analysis for early stage design tool targeted specifically at architects. The innovative aspect of the technology is in line with studies by Boland et al (2007) and Yoo et al (2006) as discussed in Theoretical framework.

### ***Sampling***

The four cases were selected using purposeful sampling defined by Maxwell (1997) as a type of sampling in which, “particular settings, persons, or events are deliberately selected for the important information they can provide that cannot be gotten as well from other choices” (p. 87). Within each case individuals were selected using purposive random sampling as advocated by Patton (2005) selecting “samples within samples.” The focus was to speak to a range of employees including architectural technologists, project architects, associate directors as well as directors in order to gain a range of experiences of using the tool.

### ***Data collection***

Data collection involved conducting semi structured interviews and focus group sessions as shown in Table 3. Focus groups were used to understand group views in a social setting whereas interviews were conducted to better understand individual views. Focus groups are particularly useful when there are power differences between the participants (Morgan & Kreuger 1993). Apart from setting the activities in a wider frame, focus group sessions helped us fully grasp the perceptions of the individuals taking part in the activity. The data collection commenced with interviews drawing on individual views that then moved to focus groups (see Table 3). Once focus groups were conducted there was sufficient information to ensure replicability reaching data saturation (O’Reilly & Parker, 2012).

Apart from setting the activities in a wider frame, interviews and focus group sessions helped us fully grasp the perceptions of the individuals taking part in the activity.

---

<sup>3</sup> Sefaira (accessed @usgbc.org on 14<sup>th</sup> April 2015)



<< Insert Table 3 here >>

Interviews and focus group sessions were semi-structured and addressed the following themes: *the role and background of participant within the organization, learning approaches* to using the modelling tools, *reasons for using the tool* and *methods for sharing 'modelling' knowledge* with client and building services engineer. Interviews and focus group session lasted between 45 and 60 minutes.

### ***Data analysis***

Data collected was analysed in NVivo using a combination of descriptive and analytic themes. Three initial descriptive categories included: 1) Organization, 2) Learning methods and 3) Energy relationships. Within the categories further subthemes were examined including: hierarchical loops, motivational blockages, client dependence, existing design drivers, uncertain effects. In a second phase, data were re-coded drawing on institutional logics using dimensions identified by Tumbas et al (2015). When discussing the organization, applicability of Sefaira in their projects as well as opportunities for using Sefaira in projects, participants mostly reflected upon reliance, adherence and compliance with existing organizational structures. These characteristics of discussions were thematically grouped under a *Logic of dependence*. When reflecting upon their learning of Sefaira, participants noted the need to commit time and energy as well as identify the practical benefits of using Sefaira to their projects. Discussions focused on learning methods were grouped under the *Logic of investment*, whilst the *Logic of risk* reflected the need to justify decisions on sharing Sefaira outputs, setting boundaries of who and when uses Sefaira as well as identifying value of Sefaira use in projects. See Table 4 for an outline of key logics characteristics across the three categories.

<<Insert Table 4 here >>

Ethics procedures were followed in conformity with University of West of England requirements and approval was obtained from the University Ethics Committee. Information and consent forms were distributed prior to each interview and focus group session whilst data were anonymized immediately after transcription.

### ***Validity, reliability and generalizability***

Validity and reliability are related research issues that ask researchers to consider whether what is being studied is applicable to real-world contexts and whether the measures that are applied are consistent (Denzin and Lincoln 2005). Guba and Lincoln (1994) discuss two key criteria by which validity can be assessed in qualitative research including credibility, whether the findings are believable and transferability, whether the findings apply to other contexts.

To ensure that the findings of this research are credible, a number of points were taken into consideration while designing, conducting, and writing the research. The points considered when addressing credibility issues include choosing appropriate methods and maintaining a rigorous and critical approach to handling data (Silverman 1997). Records were also kept of the key decisions made during the course of the research project, which helped in focusing the analysis and writing up (Blaikie 2007). Whilst the research has incorporated architecture practices with offices across the UK to contribute to credibility, it is recognized that, as a case study and exploratory research, the findings are generalisable to theory rather than statistically generalisable (Yin, 1989). Reliability of the research has been achieved through the provision of a clear methodology and selection processes to enable replication of the study by others in the future (Mason 1996). Furthermore, the same research interviewer was used for all interviews, and standard prompts and probes were provided to ensure consistency across all interviews.

## **Findings**

The findings suggest that users within the four firms portray overlapping approaches to learning, using and sharing outputs of early stage design energy modelling in their practice. These approaches were grouped under three main logics: *Dependence*, *Investment* and *Risk* (see Table 4). The findings are discussed in relation to these logics in issues such as Organization, Learning methods and Energy relationships. This is in line with the institutional concept of logics and in particular, how logics guide action and provide content to actors (see further on Theoretical Framing section 2 above).

### ***Organization***

Participants' discussion of their role in their organization and the particular project(s) where energy modelling technology was used often reflected principles of adherence and dependence. Logic assumptions coalesced in issues of working within established project workflows and against pre-existing accepted design drivers. For many participants there was a perceived reliance on others (within and outwith the organization) to use energy modelling effectively or to attempt to learn the technology in their daily practice (see Figure 1).

<<Insert Figure 1 here>>

### ***Logic of dependence: principles, assumptions and identities***

When discussing their role in an organization/project and learning/use of the technology, participants often discussed being dependent on client engagement and/or interest from their firm's management team. Participants discussed how clients were not

always seen to value participants' time spent on achieving an energy efficient design or energy efficiency within the project as an issue to spend time on. The perceived lack of interest from clients was often viewed by participants as limiting opportunities to engage in analyzing energy efficiency in their projects. One of the participants discussed their personal interest in environmental design but not being able to fully develop or exercise these interests because of a lack of client engagement or aspiration.

“...I'm interested in passive measures as a starting point and good fabric, good wall fabric, wall build up, rather than sticking renewables on top, so kind of getting the basic principles right, but I think it probably depends on how much the client engages as well as what they want...” (Studio B Participant 1)

For other participants, clients were viewed as having other needs and priorities often with little or no interest in energy issues. Thinking about energy and testing through energy modelling tools was viewed as dependent on clients' project aspirations and priorities. Participant 2 in Studio A noted how “there are more important things for the client than the energy consumption of the building” and “in order to get the right shape and size of a building “there is “little perceived need to consider energy requirements”.

In addition to perceived client interests and engagement, participants often discussed being dependent on senior management's views of their role in the firm and access to 'learning' a new technology in a project. Participant 3 in Studio A discussed how he had not been able to use the technology fully in a project. He noted how he would raise the issue in his review but simultaneously reflected upon perceived ineffectiveness of this. Participant 5 in Studio C discussed how senior management in his firm and within his project perceived the use of energy modelling in early design as potentially ineffective use of otherwise pressured 'design delivery' time.

“It seems senior managers in some teams see this as a distraction and taking away from project time as well as the programme...so junior staff are in the hands of senior managers” (Studio C Participant 5)

The logic of dependence is also characterized by participants maintaining and complying with existing project workflows and design drivers. Some of those design drivers are described as obstructing or preventing a scientific environmental approach.

“...when you look at a lot of supposedly very energy efficient, sustainable buildings, they still have this sort of eco look to them. I think the world of architects (is) still about the big vision and the big gesture and that's not so achievable if you're trying to also be energy efficient...” (Studio A Participant 2)

For others the technology was mainly used to justify an already predetermined design approach. Existing workflows were described to determine a particular design view or approach. Participant 3 in Studio C described a project where window placements had been determined prior to any energy analysis taking place

“...so the technology didn't exactly have as much effect as it could have done because (we) implemented the thinking before we used it, so it was post-justification...”

Similarly, in Studio A Participant 6 discussed how the project was constrained by planning application requirements and pre-established glazing ratios, noting how using the technology regardless of output would have little or no effect on the design. Participants often noted how potential design improvements offered by using the tool would be often discounted.

For many participants, issues of established workflows were closely related to project roles. Although an interest and potential benefit in using the technology had been largely noted, participants often reflected upon ‘others dealing with the issue’.

“My view is that I think a lot of people ... it's not that they can't be bothered, but they feel like somebody else will deal with the problem...” (Studio A Participant 2)

In Studio B Participant 2 discussed the benefit of using the technology largely in terms of being able to rely with confidence in others in the design team.

“...I was saying that I'm not a daylight and sunlighting surveyor and I'm not an energy consultant, I'm an architect and it's useful to have this information (on energy modelling) at my fingertips, but I regard it as a sort of an indication which gives some insight to what the consultant in the future will say...” (Studio B Participant 2)

### ***Learning methods***

Learning the technology for many was viewed as an easy process based on minimal training and trialing/testing of options. Learning was described as motivated by personal interests largely for the benefit of the project. In all four firms, the technology was perceived as beneficial and driven by the firm’s perceived investment in licensing the product. However, when effects of learning were observed, participants often displayed issues of uncertainty and displacement ‘not knowing where knowledge could be effectively applied’.

<<Insert Figure 2 here>>

### ***Logic of investment principles, assumptions and identities***

For many participants, learning the technology was perceived as easy and intuitive.

“...To be honest, I haven't really used it enough to say I'm an expert, but actually, in my old practice, I went to a training session when they came in and then I've been to a similar one here. It's pretty intuitive I think, it's pretty easy to use...” (Studio A Participant 1)

In addition to discussing learning as easy, most participants reflected upon apparent benefits and value of the tool. In Studio A, Participant 3 viewed the technology as ‘good because (the project) was in the early stages “and the remit was to create a building that was no-nonsense and functional”’. Despite reflecting upon apparent lack of knowledge on environmental principles, Participant 5 noted the potential ‘usefulness’ of the technology.

“I don't think so...I understand the basics of energy consumption in buildings, but I don't understand the details, so it's quite useful in that sense” (Studio A Participant 5)

Although the technology was discussed as being beneficial and useful, many participants seemed uncertain how it could be applied effectively in their project. For Participant 2 in Studio A, the technology was “not a game changer” as “it didn’t change the way that (one) thinks about what a sensible move is to make in design in terms of

energy efficiency. Similarly, in Studio C the technology was viewed as not changing the approach but mainly viewed as providing justification for established working methods.

“...Not necessarily, no 'cos I had already had a basic understanding of how it all worked, so not necessarily did it change my approach, or understanding; it was a very useful tool to prove the thinking behind what we were trying to do...”

Participants also discussed the lack of opportunities to implement ongoing use of the technology. In Studio A, Participant 5 observed how the technology had never been fully implemented in projects, although there was awareness of benefit and value. Participant 23 in Studio D discussed how the firm had spent a lot of time investing in ways to implement the technology usefully, changing protocols and work processes across projects. However, as some projects ‘lasted several years’ by the time another one came along whereby the tool could be used the knowledge was ‘out of date’.

### ***Energy relationships***

Thinking ahead and delivering for future legislation was viewed by many as a key benefit of applying early stage energy modelling in architecture. Enabling and communicating design decisions through the use of the technology was discussed by a large number of participants. However, for many participants the outputs of the modelling were viewed as a potential risk to the architects’ relationship with other design team members and the client.

<<Insert Figure 3 here>>

### ***Logic of risk principles, assumptions and identities***

Many participants viewed their role as needing to embrace ‘future thinking’ and ‘future proofing’ in order to maintain their position in an ever evolving industry. Participant 1 in Studio A noted how architects did not necessarily need more knowledge but needed to understand numeric information and to prepare for future legislation. Participant 6 in Studio A discussed his involvement in a large infrastructure London project due for delivery in 2020 and appreciating need to future proof and think ahead. Participant 2 in studio B viewed the technology as another method of communication ultimately adding value to the design outcome:

“...It gives you another, I guess, tool in your toolbox to be able to carry out high level, early assessments and also communicate to design team members and the client why certain early design decisions might have an energy impact and why it might be more or less favourable to push the design in certain directions...”

Value and benefits are also viewed through constraints and challenges. The technology for Participant 2 in Studio C is viewed as “producing pictures and reports that are client friendly, making people aware of the design constraints”. The educational and marketing value of the technology was often reflected upon.

“...You have a fee for early stage energy modelling and you can (invest in it)...but let's say you have a developer, or a client that isn't the end user, quite often it is hard to justify spending money on sustainability. However, if you maybe teach people about (how) you could sell buildings for more, therefore that's the justification for...it can be marketed as green buildings, or low carbon usage. I think there's going to be a growing market for those sort of buildings...”

Although value, opportunity and benefits were frequently highlighted, participants also discussed potential risks and liabilities. Many participants discussed not being able to share information with building services engineers early in the design process.

“We still get M&E engineers who still do their drawings by hand in 2D and then they are only prepared to put it into BIM at the very end because it takes too much time to put it in, so there are still problems there I think because for it to work, the whole point is you're meant to merge models the whole time, whereas we would find that the M&E engineers would just want to sort of drop it in right at the end, so that it doesn't waste their time...”

Across all firms, discussions often reflected upon issues of risk in terms of design responsibility and sharing of outputs with other design team members or the client. For many the risks of sharing knowledge gained from the tool with other design team members or the client were viewed as limiting opportunities for effective application of the tool in projects. Exceptions include Studio D where the tool was interpreted by some participants as beneficial to informing and justifying the design of particular building typologies such as student residences and schools as they were viewed as modular and relatively short in project duration.

## **Discussion**

The findings highlight three dominant, at times overlapping, logics of dependence, investment and risk across the firms. Early stage design energy modelling in architecture practice across the four firms investigated is largely viewed as beneficial and of value to the design outcome and process. However, participants often discussed constraints to enabling ongoing use across projects, sharing of knowledge and effective application. For many participants, decisions on use and learning were viewed as dependent on client interests or a firm's management and workflow structures. Participants' discussions were often conflicted and contradictory particularly related to perceptions of effectiveness and application. Whilst reflecting upon perceived usefulness many would note difficulties in how to effectively apply and interpret modelling outcomes. For most participants their remit of workload and workflow was viewed as bounded by their organizational or project domain. Established project and firm workflows were seen to determine how, if and when the technology was 'learnt', applied and shared.

## ***Contribution to literature on energy modelling and architecture***

The research contributes to extant literature on energy modelling in architecture in several ways. First, the study enables a contextual understanding of the organizational issues, personal views and project demands architects encounter. Organizational issues are seen to be mainly established firm and/or project hierarchies

often viewed to be obstructing use of energy modelling during otherwise constrained ‘design time’. Personal views are seen to largely support a moral, environmental and societal responsibility towards delivering considered design approaches. Project demands are seen as mostly driven by client interests and established design processes and workflows. Though some of the issues such as workflows have been discussed in previous work (Shi and Yang 2013), the focus has tended to be on suggesting new frameworks often to the exclusion of other social and organizational factors.

Second, the study’s institutional logics analytical lens allows for an examination into the principles, identities and assumptions participants draw on to justify particular decisions or views. Across the firms three logics reflected particular approaches and views with an emphasis placed on reasons for investing effort and time whilst depending on other interests and opportunities. Scholars who have studied how new technologies are used in design organizations suggest particular characteristics of institutional logics guide innovation behavior of users (Boland et al. 2007). Tumbas et al (2015) suggest organizational actors trigger organizational change by combining distinct practices from various institutional logics and incorporating them into their own profession. The findings in this paper suggest logics continue to overlap and contradict – further analysis is needed to understand how participants employ diverse logics to maintain or resist a particular approach.

Third, the research suggests there is a further need to better understand project roles and which existing or developing project or firm roles are engaged in energy modelling tasks. For many participants, responsibility for carrying out energy modelling was ‘with others’ within their own or in other organizations. Current use of the tool as discussed within this study does suggest the development of a two-tier approach whereby architects use the tool in-house to inform their design, whilst responsibility with the final modelling outputs lies with others in the design process. There is an assumption across much of the energy modelling literature that a broad range of architects participate in different aspects of energy analysis without examining the implications different project roles have on participation and adoption of new energy modelling technologies.

### ***Implications for policy and practice***

There are also practical implications for practice and policy, particularly in relation to recent changes to design practice and the wider introduction of Building Information Modelling. Sequence of design, work stages and workflows are often adapted or extended to accommodate new sequences and remits. In 2011, the RIBA published a Green Overlay to the Plan of Work (Gething 2011) with a strong emphasis on integrating sustainability thinking within traditional workflows. In 2012 the RIBA published a BIM Overlay to the Plan of Work with the purpose of enabling design and construction teams to embed digital collaborative approaches to design (Sinclair 2012). In both instances work stages within the design process were extended or adapted to accommodate new design practices, roles or approaches. The research reported in this paper suggests that adopting a new technology within an existing workflow poses challenges and can depend on an individual’s interpretation of their firm’s approach to

managing projects, staff or other design professionals. Organizational norms and conflicting project obligations can be viewed as barriers to enabling technology innovation as examined by Dossick et al (2009) and Dossick and Neff (2010). The study reported in this paper extends research by Dossick and Neff (2010) through providing a further perspective into the effects specific characteristics of approaches to workflow and workload within each firm have on how a technology is adopted.

Much research, policy and practice has focused on technical improvement strategies with less attention devoted to exploring how energy performance tools are used in design, their impact and effect on the design process, practices and built environment professionals. Although there is widespread recognition within practitioner design guidance (Sullivan 2012; Gething 2011); government construction policy (HM Government 2011; IPCC 2007) and academic literature (Eastman et al. 2011) of the need for integrated design practice, there have been few empirical accounts of the challenges practitioners encounter. Disconnects between “what some parties think is happening” and “what is actually happening” (Becerik-Gerber and Kensek 2010) have started to come to light in this study, emphasizing the need to better understand personal views and perceptions of whose interests count across projects. In this study clients’ perceived interests were often seen to prevent opportunities for energy modelling.

In addition, energy modelling and analysis was viewed as a way to justify already preconceived notions rather than a tool to inform design decisions. In most cases results of the modelling were discounted, even though participants recognized the potential value to the design outcome. Further research is needed to understand how architects interpret energy modelling results and the effects of the analysis on the design process and outcome.

There are also implications for higher education and professional development. The analysis reported in this paper would support Soebarto et al (2015) study on the need for compulsory building performance simulation teaching and learning within architecture education. A recent study carried out by Oliveira et al (2015) suggests that energy education in architecture undergraduate courses in the UK is faced with conflicting institutional, professional and personal perceptions of ‘what is needed’. Their research suggests students support the need for better application of energy related content in their courses, but are often prevented through perceived design studio interests and needs that vary from tutor to tutor. A greater understanding of how energy education could be supported or implemented in professional development courses is needed.

The implication of this study is in the analysis of architects’ approaches and views, perceived as bound by established structures of management and deeply embedded project workflows. Initial insights suggest challenges lie within particular perceived established organizational hierarchies and structures. Much remains to be explored about the way in which organizations within the built environment navigate complex design environments when faced with new digital technologies designed to extend or enable environmental analysis. The study has enabled some foundational work to understand how architects within four organizations manage conflicting institutional demands in negotiating energy modelling technology in their practice.



## Conclusion

This paper focuses on the architecture profession in the UK, acknowledging that multiple overlapping professions and other cultural contexts will enable further insights. Further work is required to determine the extent by which particular logics are emphasized in certain firms and whether a dominance of a particular set of logics enables wider use and greater effect. In addition, more integrated contributions are needed in the longer term, including a consideration of energy issues against other design and construction concerns as well as an analysis of various personal, organizational and project demands.

There is a relevant and important need for further empirical analysis and theoretical insight that develops a body of research engaged in studying energy analysis from multiple perspectives. The research carried out for this paper shows a potential way of studying energy modelling and analysis that takes into consideration the institutional logics, actors and activities involved. The identified logics although conflicting and contradictory allow participants to reach decisions and legitimate actions when implementing new technologies. Further work is required to better understand the ways particular organizations manage use of energy modelling within and across teams and in particular how particular architect roles adapt, transform or reject implementation.

**Acknowledgments:** Authors wish to thank all the participants in this study without whom the research would not have been possible.

## REFERENCES

- AIA. (2012). *American Institute of Architects (AIA) 2012, An Architect's Guide to Integrating Energy Modeling in the Design Process*.
- Anderson, J. E., Wulfhorst, G., & Lang, W. (2015). Energy analysis of the built environment—A review and outlook, *Renewable and Sustainable Energy Reviews*, 44, 149-158
- Attia, S., Gratia, E., De Herde, A., and Hensen, J. L. (2012). Simulation-based decision support tool for early stages of zero-energy building design, *Energy and buildings*, 49, 2-15.
- Balcomb, J.D. ed., (1992). *Passive Solar Buildings*, The MIT press, Massachusetts.
- Becerik-Gerber, B. and Kensek, K. (2010). Building Information Modeling in Architecture, Engineering, and Construction: Emerging Research Directions and Trends, *Journal of Professional Issues in Engineering Education Practice*, 10.1061/(ASCE)EI.1943-5541.0000023, 139-147.
- Beagle, D., Fox, W., Parkinson, J and Plotka, E (2014). *Energy: Building a Better Britain*, RIBA

- Berente, N., and Yoo, Y. (2012). Institutional contradictions and loose coupling: Postimplementation of NASA's enterprise information system, *Information Systems Research*, 23(2), 376-396.
- Boland, R. J., Lyytinen, K., and Yoo, Y. (2007). Wakes of Innovation in Project Networks: The Case of Digital 3-D Representations in Architecture, Engineering, and Construction, *Organization Science*, 18(4), 631-647.
- Blaikie, N. (2007). *Approaches to social enquiry*, Cambridge: Polity Press.
- Bleil De Souza, C. and Tucker, S. (2015) Thermal simulation software outputs: a conceptual data model of information presentation for building design decision making, *Journal of Building Performance Simulation*, 9,3
- Chung, W. (2011). Review of building energy use performance benchmarking methodologies, *Applied Energy*, 88, 1470-1479.
- Coakley, D., Raftery, P., and Keane, M. (2014). A review of methods to match building energy simulation models to measured data, *Renewable and Sustainable Energy Reviews*, 37, 123-141.
- Crawley, D. B., Hand, J. W., Kummert, M., and Griffith, B. T. (2008). Contrasting the capabilities of building energy performance simulation programs, *Building and environment*, 43(4), 661-673.
- De Wilde, P. (2014). The gap between predicted and measured energy performance of buildings: A framework for investigation, *Automation in Construction*, 41, 40-49.
- Denzin, N., and Lincoln, Y. (2005). *The Sage handbook of qualitative research*, London: Sage Publications.
- Dong, B., O'Neill, Z., Luo, D., and Bailey, T. (2014). Development and calibration of an online energy model for campus buildings, *Energy and Buildings*, 76, 316-327.
- Dunn, M., and Jones, C. (2010). Institutional logics and institutional pluralism: the contestation of care and science logics in medical education, 1967-2005, *Administrative Science Quarterly*, 55, 114-149.
- Dossick C.S. and Neff G. (2010). Organizational divisions in BIM-enabled commercial construction, *Journal of Construction Engineering and Management*, 136(4), 459-67.
- Dossick C.S., Neff G. and Homayouni H. (2009). The realities of building information modeling for collaboration in the AEC industry, in *Proceedings of the 2009 Construction Research Congress*, Seattle, WA.
- Eastman, C., Eastman, C. M., Teicholz, P., and Sacks, R. (2011). *BIM handbook: A guide to building information modeling for owners, managers, designers, engineers and contractors*, John Wiley & Sons.
- Friedland, R. (2012). Book review: Thornton, Ocasio and Lounsbury (2012) The institutional logics perspective: a new approach to culture, structure and process, *Management*, 15(5), 582-595.
- Friedland, R., and Alford, R. R. (1991). Bringing Society Back In: Symbols, Practices, and Institutional Contradictions, in W. W. Powell and P. J. DiMaggio, (eds.), *The New Institutionalism in Organizational Analysis*, Chicago: University of Chicago Press.
- Fumo, N. (2014). A review of the basics of building energy simulation, *Renewable and Sustainable Energy Reviews*, 31, 53-60.

- Gething, B. (2011). *Green Overlay to the RIBA Outline Plan of Work*, London, United Kingdom:RIBA.
- Grinberg, M., & Rendek, A. (2013). Architecture & energy in practice: implementing an information sharing workflow, In *13th International Conference of the International Building Performance Simulation Association*.
- Guba, E. G. and Lincoln, Y. S. (1994). Competing paradigms on qualitative research, in N. K. Denzin and Y. S. Lincoln, (eds.), *Handbook of qualitative research*, London: Sage, 105-117.
- Ham, Y., and Golparvar-Fard, M. (2013). EPAR: Energy Performance Augmented Reality models for identification of building energy performance deviations between actual measurements and simulation results, *Energy and buildings*, 63, 15-28.
- Harrington, L. (2001). *Computer modelling of night-time natural ventilation*, University of Loughborough.
- Hensen, J. L., and Lamberts, R. (2012). *Building performance simulation for design and operation*, Routledge.
- Hetherington, R., Laney, R., Peake, S., and Oldham, D. (2011). Integrated building design, information and simulation modelling: the need for a new hierarchy, *Building Simulation, 14-16 November 2011, Sydney, Australia*.
- HMGovernment. (2011). Skills for a green economy: a report on evidence, I. a. s. Department for Business, (ed.). City: London.
- Hobbs, D. J. N., Morbitzer, C., Spires, B., Strachan, P. A., & Webster, J. (2003). The use of building simulation within an architectural practice, *Proceedings of the Worldwide CIBSE/ASHRAE Building Sustainability, Value and Profit Conference*. Chartered Institute of Building Service Engineers (CIBSE)
- IPCC. (2007). *Climate change 2007 : mitigation of climate change : contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*.
- Korolija, I. (2011). *Heating, ventilating and air-conditioning system energy demand coupling with building loads for office buildings*, De Montfort University Leicester.
- Kraatz, M. S., and Block, E. S. (2008). Organizational Implications of Institutional Pluralism, in R. Greenwood, C. Oliver, K. Sahlin-Andersson, and R. Suddaby, (eds.), *The Handbook of Organizational Institutionalism*, London: SAGE, pp. 243-275.
- Li, X., and Wen, J. (2014). Review of building energy modeling for control and operation, *Renewable and Sustainable Energy Reviews*, 37, 517-537.
- Lounsbury, M., Geraci, H., and Waismel-Manor, R. (2002). Policy discourse, logics and practice standards: Centralising the Solid-Waste Management field, in A. Hoffman and M. J. Ventresca, (eds.), *Organizations, policy and the natural environment*. Stanford University press.
- Lin, S. H., & Gerber, D. J. (2014). Evolutionary energy performance feedback for design: Multidisciplinary design optimization and performance boundaries for design decision support, *Energy and Buildings*, 84, 426-441.
- Mahdavi, A. (2011). People in building performance simulation, in J.L.M Hensen and Lamberts (eds) *Building performance simulation for design and operation*, Spon Press

- Maxwell, J. (1997). Designing a qualitative study. In L. Bickman & D. J. Rog (Eds.) *Handbook of applied social research methods* (pp. 69-100). Thousand Oaks, CA: Sage.
- Morgan D.L. and Kreuger R.A. (1993) 'When to use focus groups and why' in Morgan D.L. (Ed.) *Successful Focus Groups*. London: Sage.
- Mason, J. (1996). *Qualitative researching*, London: Sage.
- Naboni, E. (2013). Environmental Simulation Tools in Architectural Practice: The impact on processes, methods and design, *PLEA 2013. City: 29th Conference, Sustainable Architecture for a Renewable Future*, Munich, Germany 10-12 September 2013.
- Negendahl, K. (2015). Building performance simulation in the early design stage: an introduction to integrated dynamic models, *Automation in Construction*, 54, 39
- Negendahl, K., Perkov, T., & Kolarik, J. (2015). Agent-Based Decision Control—How to Appreciate Multivariate Optimisation in Architecture, In *Modelling Behaviour* (pp. 371-382). Springer International Publishing.
- Oliveira, S., Marco, E. and Gething, B. (2015) What do we say we teach about energy? Viewed through the lens of UK architecture undergraduate education. In: *The 7th International Conference on Engineering Education for Sustainable Development*, Vancouver, Canada.
- Østergård, T., Jensen, R. L., & Maagaard, S. E. (2016). Building simulations supporting decision making in early design—A review, *Renewable and Sustainable Energy Reviews*, 61, 187-201.
- Oreszczyn, T., and Lowe, R. (2010). Challenges for energy and buildings research: objectives, methods and funding mechanisms, *Building Research & Information*, 38(1), 107-122.
- Oxman, R. (2008). Digital architecture as a challenge for design pedagogy: theory, knowledge, models and medium, *Design Studies*, 29(2), 99-120.
- O'Reilly, M., & Parker, N. (2012, May). Unsatisfactory saturation: A critical exploration of the notion of saturated sample sizes in qualitative research. *Qualitative Research Journal*, 1-8.
- Patton, M. Q. (2005). *Qualitative research*. John Wiley & Sons, Ltd.
- Pisello, A. L., Goretti, M., and Cotana, F. (2012). A method for assessing buildings' energy efficiency by dynamic simulation and experimental activity, *Applied Energy*, 97, 419-429.
- Ragin, C. (1989). New Directions in Comparative Research, *Cross-National Research in Sociology*, ed. by ML Kohn. London, Newbury Park, New Delhi: SAGE, 57-76.
- Sinclair, D. (2012). *BIM Overlay to the RIBA Outline Plan of Work*. London, United Kingdom: RIBA.
- Sullivan, L. (2012). *The RIBA Guide to Sustainability in Practice*. London, United Kingdom.
- Soebarto, V. I., Hopfe, C., Crawley, D., & Rawal, R. (2015). Capturing the views of architects about building performance simulation to be used during design processes. Conference Proceedings Building Simulation, *International Building Performance Simulation Association*

- Shi, Y and Yang, W. (2013) Performance-Driven Architectural Design and Optimization Technique from a Perspective of Architects. *Automation in Construction*, 32, 125-135.
- Silverman, D. (1997). *Qualitative research: theory, method and practice*, London:Sage.
- Thornton, P., Jones, C., and Kury, K. (2005). Institutional Logics and Institutional Change in Organizations: Transformation in Accounting, Architecture, and Publishing, *Research in the Sociology of Organizations*, 23, 125-170.
- Thornton, P., and Ocasio, W. (1999). Institutional Logics and the Historical Contingency of Power in Organizations - Executive Succession in the Higher Education Publishing Industry, 1958–1990. *American Journal of Sociology*, 105(3), 801-843.
- Tumbas, S., Schmiedel, T., and Vom Brocke, J. (2015). Characterizing multiple institutional logics for innovation with digital technologies, *Presented at System Sciences (HICSS), 2015 48th Hawaii International Conference on System Sciences*.
- Tupper, K., Franconi, E., Chan, C., Hodgins, S., Buys, A., & Jenkins, M. (2011). Building energy modeling: industry-wide issues and potential solutions. In *Proceedings of the 12th Conference of International Building Performance Simulation Association*.
- Tucker, S. (2004). *A simplified method of building thermal assessment* (Doctoral dissertation, University of East London).
- United States Green Building Council (USGBC), 2015, Building energy Modelling and Sefaira, available on <http://www.usgbc.org/education/sessions/trends-building-energy-modeling-and-sefaira-demonstration-4978817> [accessed May 2015]
- Weytjens, L., & Verbeeck, G. (2010). Towards 'architect-friendly' energy evaluation tools, In *Proceedings of the 2010 Spring Simulation Multiconference* (p. 179). Society for Computer Simulation International.
- Yoo, Y., Boland Jr, R. J., and Lyytinen, K. (2006). From organization design to organization designing, *Organization Science*, 17(2), 215-229.
- Yin, R. K., (1989), *Case Study Research: Design and Methods*, Second Edition, Newbury Park, California: Sage Publications, Inc.
- Zapata-Lancaster,G and Tweed,C (2016) Tools for low energy building design: an exploratory study of the design process in action, *Architectural Engineering and Design Management*, 12(4)
- Zhao, H.-x., and Magoulès, F. (2012). A review on the prediction of building energy consumption. *Renewable and Sustainable Energy Reviews*, 16(6), 3586-3592.