IDENTIFYING NON-TECHNICAL BARRIERS TO ENERGY MODEL SHARING AND REUSE

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ABSTRACT
Energy models generated during the design phase of new and/or retrofitted buildings could - in principal - be converted into calibrated energy models and used for building operation purposes. However, while the idea is old, this rarely ever happens in practice. This paper aims to understand whether this approach is technically feasible based on today’s design-phase models and what non-technical barriers might stand in the way of its implementation. The authors surveyed 118 architects, 34 real estate owners and 154 engineers/energy modellers and found that 75% of the engineers/energy modellers believed that their models could be used by a third party for commissioning and building operation. Nevertheless, the survey revealed existing challenges for this model reuse. These challenges included: the sometimes unrealistic portrayal of the actual building in the design-phase models, a lack of required skill on the building operations team, and difficulty in communicating modelling assumptions. Of those who believed this model reuse was feasible, 80% indicated either they would not share their models with the owner, or they would require certain stipulations for sharing. This paper provides suggestions to energy modellers, building owners, and software developers for overcoming these challenges and includes references for relevant legal contracts. Keywords: Building Energy Simulation, Survey, Building Operation, Legal Contracts

1. INTRODUCTION
Energy models are computer-based simulations used to predict the energy use of a building. These models are typically prepared by specialist consultants as a service for the owner and design team for new building or retrofitting projects. During the design-phase, energy simulations can be used to compare relative changes in energy use for different design options. Building owners increasingly use energy models to demonstrate energy savings for green building rating systems such as the U.S. Green Building Council’s LEED system (USGBC 2009) and ASHRAE’s new standard 189.1 for high performance green buildings (ANSI/ASHRAE /USGBC/IES, 2010). Compliance with these programs typically requires detailed, and therefore expensive, energy models, with an estimated modelling effort of 120 person-hours for a typical commercial building (Korber-Gonzalez, 2011). However, after the design phase, these costly energy models are typically just discarded. This practice provokes the question; could design-phase models serve other, value-adding purposes?

Calibrated energy models are models of existing buildings under operation for which key simulation inputs such as occupancy and HVAC schedules are set according to actual building use rather than according to assumptions made during design. Calibrated energy models can be valuable for verifying the performance of installed energy conservation measures (IPMVP, 2006). Other possible uses are to normalize the building energy consumption with respect to occupant behaviour and weather for the sake of comparison between buildings (Jensen, 2007) or to help detect and diagnose functional problems in buildings, (Claridge, 2011).

This paper is concerned with this last usage, which has previously been termed ‘continuous commissioning’ or continuous performance monitoring (Claridge et al, 2000). The basic premise of the approach is that most commercial buildings do not perform optimally with respect to energy use. For example, Liu et al (1994) showed that the energy consumption of commercial buildings could be reduced by about 20% with improved operations and maintenance measures. Claridge et al (2000) demonstrated, in a study of 34 academic buildings in Texas, U.S., that a payback of one to two years could be expected with ongoing-commissioning. In one type of ongoing-commissioning, sometimes called automated fault detection and diagnostics (FDD), a computer periodically compares the metered to predicted performance of a whole building or individual system components. If there is a large discrepancy between the metered and predicted performance, for example if equipment fails, the FDD system can then alert the building manager. This FDD approach has been researched and tested (Jacob et al. 2010, Kissock et al. 2002) and there are even initial commercial solutions available based on this research (Katipamula, 2003).

These systems typically use so-called “black-box”
models, which are based on historical measured energy use of a building with no or limited knowledge of the physical processes in the building. These models, typically multilinear regression or automated neural networks models, rely on a limited set of input data and learn to anticipate the energy consumption over time for various conditions such as ambient temperature and day-type (weekday or weekend). Their main attraction is that they require only a moderate amount of time to construct, (Katipamula & Brambley, 2005) so that they can be implemented at a relatively low cost. Their main limitation is that they can merely detect whether the building behaves consistently over time under comparable usage and climatic boundary conditions without knowledge of whether the absolute energy use is at all appropriate for that building or not. E.g. if electric lighting or a pump are accidentally left running all the time a black box model is unable to detect such a shortcoming since it does not have any knowledge about the actual building or reference data for comparable buildings. To overcome these limitations, an alternative idea is therefore to use a physically based “white-box” model that has sufficient information about a building to gauge its absolute energy performance. A white-box model can potentially help an owner to verify whether a building performs according to its original design intentions. Being based on first principle, it also does not need any training period to function and allows the exploration of ‘what if’ scenarios if retrofitting measures are being considered for the building. On the flipside, a key disadvantage of a white-box models is the time/cost required to create it. The question is whether the required additional modelling effort for white box models can be justified by increased potential energy savings vis-à-vis the use of black box or no models.

One possibility to skew this analysis in favour of the white box model is to use an existing design-phase energy model (if available) as a starting point and calibrate it so that it can function as a white box model. One argument in favour of this approach is that an owner who already paid for a design-phase building energy model has a natural interest in verifying that his/her building operates as designed. For such an owner the natural question would be can the design phase model be turned into a calibrated white box model and at what cost.

Design-phase models, are typically not immediately functional as white box models because actually measured building energy use differs for most buildings from the simulated building performance. This fact is exemplified in Figure 1 for 98 LEED certified buildings. The figure is based on a dataset of buildings completed from 2000-2006 and for which the New Buildings Institute collected various information including measured and simulated building energy use intensity (EUI) (Turner & Frankel, 2008).

If design-phase energy models were perfect predictors of actual energy use, all data points in Figure 1 would lie on the solid line. However, the figure shows a somewhat discouraging R² value of 0.4, illustrating the need to calibrate those models before using them for continuous performance monitoring. The authors prepared an online survey investigating these issues. The results of this survey, along with some possible solutions to the barriers indentified by the survey participants, are presented in the following.

2. SURVEY DESCRIPTION
An online survey was conducted from July 9th to September 18th 2009. The questionnaire was approved by the Harvard University Standing Committee on the Use of Human Subjects in Research under file number F17883-101. The main emphasis of the survey was to better understand who on the design team owns and obtains access to the energy model of a building, what role the model currently plays during building design, and how the use of the model could be extended to the overall lifetime of a building. Additionally, the survey included questions about Building Information Modelling (BIM), Integrated Project Delivery (IPD), and post-occupancy evaluation (POE); however, these topics are outside the scope of this paper. The focus groups for the survey were building owners (preferably informed owners of multiple buildings), architects, HVAC engineers, and energy modellers.

The authors primarily used popular email lists such as 

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1 Software used: StataCorp. 2007. Stata Statistical Software: Release 10. College Station, TX: StataCorp LP. These are LEED-NC version 2 certified buildings. Therefore, the energy models followed ASHRAE 90.1 Appendix G protocol. The natural logarithm of each EUI was used to highlight the relative portion that the estimates are off, rather than the absolute units.
2 In this paper terms such as “owner”, “architect”, etc. may refer to a person or an entity; e.g. an owner may be a government or an institution.
as onebuilding.org to recruit survey participants. The survey used a branching format, meaning that a respondent’s answers led to an applicable set of follow-up questions. Because of this format and the option to skip questions, not every participant answered each question. Much of the discussion in this paper stems from the more popular themes apparent across the survey responses. The authors derived the remainder of the discussion from outside literature, expert interviews, and an investigation of digital file precedents, namely CAD (Computer Aided Design) and BIM.

3. SURVEY RESULTS

3.1 Participants’ Background

Responses came from 31 countries across the globe with the majority from the United States (60%) and Canada (13%). A total of 306 individuals participated, identifying themselves as: 116 energy modellers/energy consultants, 38 design engineers, 34 real estate owners, and 118 architects. These numbers suggest that the survey results are somewhat representative for the community of energy modellers, especially in the U.S. For building owners and architects the sample percentage is of course much smaller, so their responses can be interpreted merely as a general indication of the position of these groups on these issues.

The engineers/modellers were a slightly more international group than the other two with the majority (54%) coming from outside of the U.S. The real estate owners had a median portfolio size of 160,000 m² (1.75 million ft²), and 75% of them had participated in six or more new construction or retrofit projects in the previous decade. The architects’ firms ranged in size from less than 5 employees (26%) to more than 50 employees (47%). The following presents the most relevant survey results. The complete survey questionnaire is available from the authors.

3.2 Current Practice

3.2a Owners: Do you track and benchmark your building energy use? Of the 24 respondents, 62% answered yes. When asked to describe these “energy tracking” procedures, they listed a range of activities. At one extreme, two respondents mentioned nothing more than reviewing utility bills. At the other extreme, a respondent mentioned a National Renewable Energy Laboratory (NREL) 2-year evaluation of their building.

3.2b Owners: Do you have any commissioning procedures in place to verify that your buildings function as designed? A total of 61% [14] of owners said yes. However, it should be noted that in the write-in description of these procedures only 67% [6] of write-in respondents actually described commissioning procedures that exceeded normal construction closeout practices in the opinion of the authors. Although conclusions cannot be drawn from such a small sample, the results imply that the real estate industry may lack a clear understanding of what “building commissioning” means.

3.2c Architects: Are you currently evaluating the energy performance of your projects? Select all that apply. A total of 100 architects responded as follows: No, we are not currently doing this because it is too costly [6]. No, we are not currently doing this because our clients are not interested in the subject [9]. Yes, through the use of rules of thumb and other general sustainable design guidelines [58]. Yes, we are using in-house energy modellers to track the energy performance of our projects throughout the design and construction process [33]. Yes, we are usually doing this through an initial consultation with an outside energy consultant at the beginning of a project [25]. Yes, we are usually doing this through an outside energy consultant at the end of a project to get LEED certification [26]. Yes, we are continuously working with an outside energy consultant throughout the design and construction process [34].

3.2d Architects: How frequently do the results from the energy model directly change your design? A total of 62 architects responded as follows: Always [6], Quite often [33], Occasionally [18], Rarely [5], Never [0]. Cross-referencing the responses from questions 3.3c and 3.3d produces interesting results. As shown in Figure 2, the use of in-house versus outside energy consultants/modellers did not significantly affect the frequency with which the energy model influenced
the design. However, the results indicated that the timing of the interaction with the energy consultants/modellers was significant. The architects utilizing energy consultants/modellers only at the end of the project for LEED documentation reported that the model impacted their design significantly less frequently than those using consultants/modellers at the beginning or throughout the project (P-value = 0.019). This finding confirms the popular belief in the benefits of earlier design-stage energy modelling.

3.2e Engineers/Modellers: What software programs are you primarily using and for what task? The 116 respondents listed, among other types of programs, 14 different energy simulation programs. No single energy simulation program was listed by more than roughly 20% of the respondents. This diversity is surprising in comparison to other arenas, such as CAD, in which a few software packages dominate the market.

3.2f Engineers/Modellers: Once brought into a project, who is typically paying you? Select all that apply. A total of 110 respondents answered as follows: Architect [71], Owner [73], General Contractor [18], Mechanical Engineer [16].

3.3 Owner Interest in Using Models

Owners: If properly calibrated, an energy model can help you, the owner, to closely monitor and often substantially lower the energy use of your buildings as well as alert you if parts of your HVAC delivery systems fail or become less efficient over time. To make such use of an energy model you need the help of a trained building modeller. Which of the following choices best describes your reaction to this statement? I might be interested in using energy models to enhance building operations even if it required additional training of one or two of my building services associates [15]. I am, in principle, interested in the use of energy models to enhance building operations but I would prefer to outsource this service [6]. I am not interested in this service because my buildings already function properly [2].

The owners surveyed indicated an overwhelming positive interest, 91% [21], in utilizing energy models in ongoing-commissioning, at least in the theoretical best-case scenario described. These responses indicate that - at least in the limited sample of owners surveyed - there existed a group of owners potentially interested in providing some form of compensation for in-house or outsourced services to use energy models for ongoing-commissioning. However, since this sort of advanced strategy is relatively new, these respondents cannot yet fully appreciate the cost and complexity of implementing this strategy.

3.4 Feasibility of Model Reuse

Given that a potential commercial interest in continuous commissioning via design-phase energy models has been established, the focus shifted to the providers of these models

3.4a Engineers/Modellers: Do you think that your energy models could - in principle - be used by the owner or another member of the design team during commissioning and operation? The majority [88 of 118] responded with ‘yes’. For the authors the fact that 75% of the participating energy modellers - who constituted a sizeable portion of the overall industry - indicated that they believe that their models can be used in commissioning and operation was the central outcome of this survey.

3.4b Why could the model not be used by another party? Example: The model is too specific or complicated for somebody else’s use. The remaining 30 respondents who did not believe their energy models could be feasibly reused were asked this question. They provided 28 write-in responses, which the authors summarized as follows: My model is too specific or complicated; my assumptions would not be understood by another [18]. My model does not adequately represent the actual building; it was intended for a relative comparison of design options, not an absolute prediction of energy use [7]. I do not believe that owners have professionals on-staff with the requisite skills to use the model [2]. I do not have a model [2]. I want to protect my intellectual property [2]. I am concerned about liability [1].

Some notable quotes from these responses included:

“[I] want to preserve my competitive edge: a restaurant owner [doesn’t] give away his recipes.”

“[Another] party could change parameters and blame us for results saying it was ‘our model.’

“Everyone follows his own way to set up the energy models. It will consume more time to understand [an] others’ model than to build a new one.”

3.4c Would you be willing to adapt your energy model, potentially even change the simulation program that you are normally using, if the owner made this a firm contract requirement? The

5 In 2010 there existed at least 123 whole building energy simulation tools (U.S. DOE). http://apps1.eere.energy.gov/buildings/tools_directory/
respondents who did not believe that their energy models could be feasibly reused were given this follow-up question. They [28 of 30] responded as follows: I would not adapt my model [4]. I would adapt and share my model under the conditions specified below [question 3.5d] if the owner is an important client [12]. I would change the simulation program and share my model under the conditions specified below [question 3.5d] if the owner is an important client [13]. I would not change the simulation program that I use, because my internal workflows are too closely linked to it [6]. Other [6]. The write-in responses under “other” can be summarized as: I do not have a model [2]. The answer depends [2]. I would sub-contract the modelling to someone who uses the requested software [1]. I would recommend that the owner change software [1].

Owners wishing to use the digital energy model should note that only 14% of all modellers [4] indicated that they would not adapt their model in any way.

3.5 Willingness to Share Models

The previous sections investigated the interest in, and the perceived technical feasibility of, reusing design-phase energy models. Next, the survey investigated the willingness of professionals to share these models. The following sections first probe digital file sharing practices in general and then the willingness of professionals to share their energy models in particular.

3.5a Engineers/Modellers: What are your typical project deliverables? Select all that apply. The 114 respondents answered as follows: Report specifying simulation assumptions, results and design recommendations [108], Suggested design alterations [91], Electronic copies of the simulation files [33], Product specifications [28].

3.5b Have you ever provided a digital model of any kind to another member of the design team including the owner? Owners: Have you ever received a digital model of any kind...? Engineers/Modellers: 55% [65] responded ‘yes’. Architects: 85% [81] responded ‘yes’. Owners 72% [21] responded ‘yes’.

3.5c If yes, what type of model (CAD, BIM, energy) and what did the other party do with it? Architects [95] and engineers/modellers [118] wrote-in responses mentioning: BIM [42], CAD [28], preliminary design models [10], and energy models [5]. Two write-in responses described the use of energy models beyond the design phase: for “M&V [measurement and verification] implementation” and “operational follow-up”. These responses are important, because they show that the use of design-phase energy models post-construction is not only the goal of academic researchers but also the reality of practicing professionals.

These responses to the questions above indicate that the architects and owners were more involved in file sharing than the modellers/engineers. There could be a number of reasons for this. For example, many clients may not request a copy of the energy model, because they do not yet perceive a use for it.

3.5d For those Engineers/Modellers who thought their model could be used by the owner or were willing to adapt their model: Under what circumstances would you be willing to share your energy models with the owner or the rest of the design team? Select all that apply. The responses are shown in Figure 3. By offering the multiple-choice answers shown, the authors strove to understand the stipulations surrounding the professionals’ willingness to share, as well as any reasons for their unwillingness to share their energy models. As Figure 3 shows, intellectual property issues, protecting trade secrets, liability concerns, and appropriate compensation were all concerns. Of those engineers/modellers who believed that their model could be feasibly reused by the owner, 84 answered this question. Of those 84, 80% indicated they would not share their models with the owner or design team, or they would require certain stipulations for sharing. Meanwhile, 20% [17] indicated they are already sharing their models, and 24% [20] would request an additional fee for preparing the model for sharing.

This question also provided an opportunity for write-in responses. The most relevant responses are summarized below:

- One respondent suggested a hand-off meeting as a way to familiarize the next user with the peculiarities of the model.
- Another explained that his/her willingness to share the model depended on who might be using it: “high level interaction is welcomed, but not training someone to use our model.”
- Two respondents disagreed over the current capabilities of owners: One respondent wrote, “I like the concept of an owner that would [use] our model after the construction work... Owners with the requisite knowledge/skill set and interest are hard to come by however.” In contrast, the other respondent mentioned, “I am involved in a lot of Energy Performance Contracting where the energy model is scrutinized by the Owner and Utility for establishing economic models, baseline energy use and fee. I think that there is a lot of newly developed sophisticated in the client’s review of my work product that in the near future, the owner’s knowledge will equal that of the energy modeller....”
- Five respondents described their liability or intellectual property concerns and stipulations.

3.5e For those who indicated they would request an
additional fee for sharing their energy model: How high would that additional modelling fee roughly be? Example: 25% of the regularly paid fee for service. A total of 28 Engineers/Modellers provided write-in responses. The answers varied greatly. The range of answers included both “hourly” and “5-50% of the energy modelling fee.” Generally, the answers gravitated around 20% of the total energy-modelling fee. Some of the respondents answered with a percentage, but did not specify to which fee this percentage would be applied. The authors used their judgment in interpreting these responses. Some of the respondents qualified their answers by explaining that the fee would be necessary to pay for additional work such as gathering background documentation or switching the model to a more user-friendly format.

3.6 Model Ownership

Owner: Who, in your opinion, owns the CAD, BIM and energy models that you commission? Architects and Engineers/Modellers: Who, in your opinion, owns the energy model? As illustrated in Figure 4, this question sparked a great deal of confusion. Surprisingly, each of the professional groups surveyed predominantly believed that, in the absence of specific contract language, they themselves owned the energy model. The question offered an opportunity for write-in responses. These responses confirmed this confusion as some respondents stated that whoever built the model owns it [5], while others stated that whoever paid for the work owns it [12].

4. DISCUSSION

4.1 Context

Among other topics, this survey investigated the willingness of professionals to share their digital energy models. To understand the importance of this topic, the reader may consider the history of two other digital file precedents: CAD and BIM. Through the 1990’s and early 2000’s in the United States, CAD file sharing, especially between the design and construction team, was often avoided completely or accompanied by, in the words of the American Institute of Architects (AIA), such “draconian disclaimer notices” (AIA, 2007a, Noble & Heart, 2008) that the recipient sometimes would rather start the drawings from scratch than assume the risk. As a result, overall industry efficiency suffered. With the advent of modern digital file sharing agreements (for example: AIA, 2007b) the situation has improved. Problems persist even today when, in theory, BIM offers a platform for architects, engineers, and contractors to contribute to or extract information from one coordinated digital file. However, anyone familiar with practice today knows that BIM is seldom used to its fullest capability. Instead, sharing of the model is often hindered by concerns of liability, proper compensation, and other issues likely of more interest to lawyers and accountants than designers and software developers. Once again, industry efficiency suffers.

4.2 Advice to Energy Modellers

Although not specifically stressed in the survey responses, it seems that creating a model that would eventually be used for commissioning and operations could be a new business opportunity for energy modellers.

"Human Interoperability": For one person to reuse another's model, “human interoperability,” or the ability of the future user to understand the original author's work, would need to be established. Documenting assumptions and using universal modelling standards could help. Such standards could be promoted through organized programs such as ASHRAE/IBPSA/IESNA’s Building Energy Modelling Professional Certification. Another solution could be the establishment of longer-term modelling & commissioning partnerships that would allow individuals to develop familiarity with each other’s work.

"Intellectual Property": The survey revealed confusion over model ownership. In the U.S. at least, it is no wonder that this confusion exists. Although the U.S. Copyright Act (Title 17 of the U.S. Code, 1976) and the Architectural Works Copyright Protection Act

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6 One may expect that the discrepancies over model ownership may be related to a difference in local laws; however, these responses were not correlated to the respondent’s location. Some readers may find it surprising that the architects received a significant portion of the vote. The authors assume this is because architects both build energy models themselves, and, as demonstrated in question 3.3f, often pay for the model.

7 www.ashrae.org/certification/page/2491
(1990) govern this issue, both laws show a lack of sensitivity to post-digital age works (Noble, 2010). According to Noble, the design and construction industry usually interprets these laws to mean that the creator of content owns that content (Noble, 2010 & 2011). However, project teams often handle specific situations by written contract. Regardless of ownership, unlike an author or musician who receives royalties for each copy sold, building modellers usually make one-of-a-kind products and are paid for their services. Therefore, the bigger issue of concern regarding intellectual property is really that of protecting trade secrets.

Trade Secrets: The survey responses revealed a fear among some expert energy modellers of losing their competitive edge if beginners gain access to their custom tools and modelling techniques. Therefore, in order to share the digital energy model, some modellers desire protection against it falling into the hands of the competition. Although not foolproof, a non-disclosure agreement (NDA) can help. These have become so commonplace across a number of industries that free NDA templates are readily available on the internet. More specific to the building industry, the American Institute of Architects documents E201 and C106 include a clause limiting the disclosure of confidential information to “those who need to know the content of the Confidential Information in order to perform services... solely and exclusively for the Project...” (2007b).

Liability: The survey responses also identified liability as a perceived barrier to digital model sharing. For concerned modellers, contract language indemnifying professionals against certain claims, is easy to find. For example, the ConsensusDOCS BIM Addendum (2008) states, “Each Party shall be responsible for any Contribution that it makes to a Model.... No Party involved in creating a Model shall be responsible for costs, expenses, liabilities, or damages which may result from use of its Model beyond the uses set forth in this [document].” The BIM Addendum refers to models actually used to construct the building. Therefore, considering the relative human safety (and cost) implications, one could argue that the liability stakes may be even lower for energy models. Therefore, liability certainly seems like a surmountable hurdle to energy model sharing.

4.3 Advice to Software Developers

If energy models are to be shared, and if the diversity of simulation tools mentioned in the survey responses continues, the further maturation of universal file formats and transfer workflows will be vital. In addition, if the model is meant to be available for use in the future, ideally this universal file format will evolve with backwards compatibility.

Meanwhile, software controls could help liability-shy professionals. These controls could not only lock portions of the model, as mentioned, but also log changes. Because of the ability to log changes, “concerns about liability for stealing or modifying data are not the monsters they are being made out to be” (Ashcroft and Hurtado, 2009). This statement refers to digital design and construction files in general, but one can imagine how it could apply to energy models.

In addition, access controls could be used to hide proprietary modelling information from future users. These same controls could help simplify the model interface, for example by only giving the building manager access to certain parts of the model. This would help solve some of the “human interoperability” issues previously discussed. Software that makes it easier to document modelling assumptions also would be helpful in this regard. Alternatively, the authors’ wish list includes specialized on-going-commissioning software able to read-in the energy model and provide a simplified interface for the building operations team.

4.4 Advice to Owners

It seems likely that most building owners will not be able to afford a specialized employee on-staff to make use of a building energy model. However, owners of large real-estate portfolios may. For portfolios large and small, the authors can envision a future scenario with more outsourced building monitoring services where individual managers would monitor several buildings remotely. In this way, building managers could become more specialized perhaps making the use of energy models in operations more realistic.

Building owners interested in utilizing design-phase energy models post-design should take measures to ensure that the delivered product meets their needs. First, the prudent owner should establish permission...
to use the model in this way. Some owners use written contracts to obtain legal ownership of the model; however, a more fair approach may be to establish a *license* for the intended model uses. For reference language, see AIA 2007a and the other AIA and ConsensusDOCS references listed herein. Second, the model would need to be updated with any building changes that occurred throughout the design and construction process. Third, the survey results highlighted the importance of establishing "human interoperability", as defined above. Therefore, owners wishing to reuse energy models should require the documentation and submission of modelling assumptions.10 These owners should also request that the modeller organize and label the model for ease of future use. In addition, scheduling a hand-off meeting may be beneficial to familiarize the next user with the peculiarities of the model. Fourth, the owner should ensure that the model will be delivered in the desired software format11. As the survey results indicated, a wide array of software packages are in use, and it is highly unlikely that the owner's team will be familiar with all of them. Finally, since all of the tasks described above require effort on the part of the modeller that is likely outside the normal project modelling scope, the owner should expect to pay an additional fee for these services. The authors offer a rough estimate of 40-hours of additional work beyond a typical LEED-compliant model. Most importantly, the owner should establish these end-goals up-front, otherwise important opportunities may be missed.

Although not written specifically for energy models, the State of Ohio Building Information Modeling (BIM) Protocol (2010) offers a precedent for owners wishing to define their model needs. This document covers topics such as defining end-uses and specifying levels of model detail and accuracy. Fortunately for owners, almost half of the engineers/modellers surveyed [12 of 28] would be willing to adapt their model if an important owner made it a contract requirement.

### 4.5 Future Research

While the survey results represented an international view, the legal research in this paper focused on the U.S. The authors recommend a similar exploration in other countries.

This paper dealt with the *non-technical* challenges in design-phase energy model reuse. One survey response summarized the *technical challenge: Energy modelling “is a comparative exercise, not a predictive exercise. Although energy models can be converted to more predictive type of models by calibrating them against a building’s actual historical energy usage, this is a whole other exercise that is potentially even more involved than the original design phase type energy modelling exercise itself.”* The authors agree with that generalization of today’s models. However, the important question is not whether calibration is more difficult than creation of the original model. The question to be answered is whether the benefit of reusing the model can outweigh the cost of preparing it for reuse. With the poor performance of our commercial buildings leaving such a large margin for improvement, the potential benefit seems great. Carefully documented case studies are now required to quantify the financial and energy benefits of using calibrated energy models for operational and financial decision-making.

### 5. CONCLUSION

This paper presented results from an online questionnaire on the potential use of calibrated design-phase energy models in building commissioning and operations. The 306 responses reflected a sizable interest, especially in the energy modelling community, in this topic. Considering the enormous energy savings potential of commissioning and ongoing commissioning, the question looms whether utilizing the energy model in these processes is technically feasible and whether professionals are willing to engage in the process. The survey results indicated that 75% of engineers/modellers believed it was, in principle, feasible with their models. Furthermore, most were willing to share their digital models, especially when protected with a few simple contract stipulations. The limitations of design-phase energy model are clearly listed in ASHRAE 189.1, and the authors acknowledge the technical challenges surrounding model calibration and reuse. Nevertheless, energy simulation is a powerful and relatively young tool, and the boundaries of its utility deserve more exploration.

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10 As a reference, Tupper &Fluhrer 2010 recommends a list of modelling assumptions that should be documented. The list was not necessarily intended for model reuse in commissioning and operations but provides a decent reference for owners nonetheless.
11 Universal file formats, gbXML (Green Building Extensible Markup Language www.gbxml.org) and IFC (Industry Foundation Classes www.buildingsmart.com), have been developed to make transfers between software packages possible. However, currently, the final user will experience a smoother workflow if the model is created in the software he/she intends to use.
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