MARKET IMPLICATIONS OF OPERATIONAL PERFORMANCE VARIABILITY IN CERTIFIED GREEN BUILDINGS

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ABSTRACT

Voluntary green building certification tools are promoted as a market-driven solution to improve operational environmental performance in the commercial property industry. Because certification often occurs pre-occupancy, simulations of resource efficiency (especially energy consumption) are used to reward operational performance. This paper examines the effect on the first 450 LEED green building certifications when credits for simulations of operational energy performance are replaced with two models of post-occupancy energy performance. Results show that approximately one-third of current LEED buildings are likely misrepresented to the market as a result of differences in measured energy consumption relative to expectations. Two likely reasons for this misrepresentation are presented. First, the precision of contemporary energy simulations is less than the narrow thresholds for awarding LEED credits. Second, many buildings are sensitive to the loss of a single credit because their designs only meet minimum requirements. Similar outcomes can be expected in Australasia because the mechanism for awarding and weight given to energy efficiency credits in the final assessment is similar to LEED. These results present a conflict of interest between building owners and those who value building performance. Eliminating this conflict is one of multiple benefits that are likely to result from a change in certification process that involves a level of ongoing performance assessment.

KEYWORDS:

sustainable, commercial property, assessment, LEED, energy, performance

INTRODUCTION

The property industry uses voluntary self-regulation to further the delivery of environmentally benign and natural resource efficient buildings, which are often called green buildings. Beginning with the UK Building Research Establishment Environmental Assessment Method (BREEAM) in 1990, voluntary certification tools have sought to stimulate commercial property markets for green buildings around the world. Using a small number of prerequisites and a variety of optional standards (commonly called "credits"), commercial building owners can obtain third-party certification for a building that conserves natural resources (energy, water, and materials), creates a healthy working environment, and reduces environmental damage relative to conventional building standards. The suite of tools under the Leadership in Energy and Environmental Design (LEED) brand, developed by the industry-led United States Green Building Council (USGBC), are the dominant voluntary assessment systems in North America. In Australia and New Zealand, national green building councils have developed similar certification systems using the Green Star brand.

In most markets, certified green buildings currently occupy a low proportion of the market for commercial building space (Fuerst and McAllister, forthcoming). However, about one-third of firms in the global US$4.7 trillion construction market are "largely to fully dedicated" to green building (McGraw-Hill Construction 2008), so there are high expectations for growth. Despite this emerging interest in green building procurement, commercial buildings are long-lived assets, so the market for green building space will take time to mature.

Investors, developers, owners and tenants appear willing to pay for the benefits of green building certification. Stated preference studies often find that green building is perceived as an important future direction for the industry (see, for example, McGraw-Hill Construction 2008; Myers et al. 2009). With ten years of green building certification in the United States, property scholars have begun to investigate the revealed preference of premiums paid and occupancy rates for certified commercial property. Using hedonic regression, most have concluded that LEED certification provides statistically significant increases in property value, rents and occupancy rate (Wiley et al. 2010; Fuerst and McAllister, forthcoming).

More specifically, the market is willing to pay for two main classes of benefits. First, green building can deliver "intrinsic benefits" – improved operational performance through reduced costs, increased revenue, or reduced risk (Elkington 1994; Reinhardt 1998; Edwards 2003; Kats et al. 2003; Matthiessen and Morris 2004; Corbett and Muthulingam 2007). Alternatively, a green building can provide "market signalling", where a credible signal is the sole source of added value. There are a variety of motivations behind market signalling, such as qualification for tax credits, strategic market differentiation, perceived legitimacy, delaying regulatory pressure, and increased competitiveness (Reinhardt 2000; Corbett and Muthulingam 2007; King and Toffel 2009).

Recent research has attempted to understand the relative contribution of these two drivers in the business case for green building. Corbett and Muthulingam (2007) fit data on LEED-certified buildings to models of decision making and tentatively conclude that organisations first choose a level of certification (market signalling) and then choose how many credits to adopt over the necessary threshold as a result of pursuing intrinsic benefits. The distribution of credits obtained above minimum requirements for a signal is skewed towards the minimum (Figure 1), suggesting that market signalling is the dominant driver. Anecdotal reports on the dominance of signalling are common (see, for example, Schendler 2009).

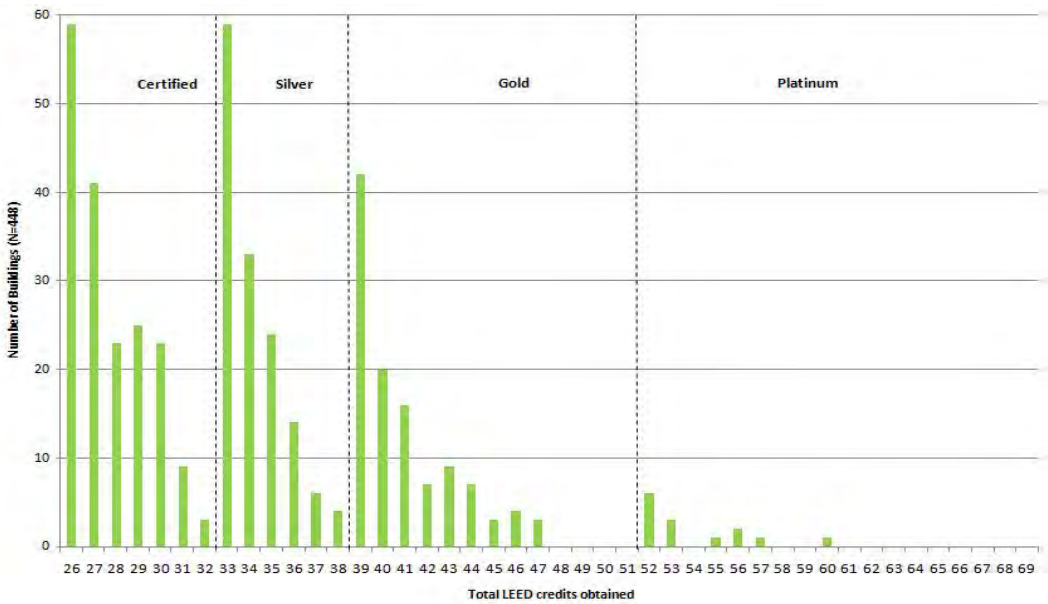

Fig. 1 Frequency of total credits obtained across all LEED-certified buildings (New Construction version 2) up to 1 September 2006 (the dataset in this study). Dashed lines indicate signalling thresholds.

The primacy of signalling may have unwanted side effects. Hoffman and Henn (2008) discuss how signalling can lead to "misdirected attention" on credit requirements, potentially leading to sub-optimal performance outcomes and barriers to innovative solutions.

A potential weakness in the certification of buildings is that the process almost always takes place at the design or as-built stage of a project – ongoing assessment and re-certification is rarely performed. In studies comparing design intentions to operational outcomes, green buildings have been shown to deliver on the magnitude of operational resource efficiency at the societal scale, but there is high variability in performance at the individual building scale (Turner and Frankel 2008; Newsham et al. 2009).

Given the observed variability in performance at the individual building scale, this paper models how certification scores (Figure 1) could change if post-occupancy resource consumption is used in place of simulated resource efficiency. Because of its use in both pre-occupancy and post-occupancy studies, the LEED for New Construction certification system (predominantly in North American markets) will be examined. After an introduction to the process of green building certification and more detail on the findings of post-occupancy studies, models will attempt to describe how Figure 1 could be amended to account for operational variability. The findings and implications for the property industry are then discussed.

GREEN BUILDING CERTIFICATION TOOLS AND ENERGY PERFORMANCE

Most certification tools worldwide have three to five distinct certification levels, with higher levels achieved by implementing a greater percentage of optional credits. LEED for New Construction (version 2) features 69 optional credits in total and four distinct certification levels: a "Certified" rating is given to buildings that obtained 26–32 credits; a "Silver" rating to those that obtained 33–38 credits; a "Gold" rating to those that obtained 39–51 credits; and a "Platinum" rating to those that obtained over 52 credits.

Certification occurs at distinct phases in the building procurement process, which is split into the design stage, as-built stage, and operational (in-use) stage. In most cases, once a building has been certified at a particular phase, it retains its assessment for the life of the building. Exceptions to this are in-use phase certifications, such as the National Australian Built Environment Rating System (NABERS) or LEED for Existing Buildings: Operations and Maintenance, where updated performance data is required every year or every five years respectively. As a result, operational stage tools function in a similar manner to financial reporting practices (Gabe et al. 2009).

Operational energy efficiency is an important component of certification schemes, and has been the subject of studies of green buildings in operation (Turner and Frankel 2008; Newsham et al. 2009). Energy efficiency factors in nearly one-third of all optional credits in LEED (Newsham et al. 2009). Of relevance to this study are eleven optional credits obtained through simulation of operational energy consumption (in dollars) relative to a baseline (standard-compliant) building (Table 1).

Table 1. Optional energy credits for consumption costs relative to ASHRAE 90.1-1999* standard. Efficiency requirements are higher for new buildings than for major renovations of existing buildings eligible for certification under LEED for New Construction. Source: USGBC (2003).

% Cost Reduction (new/existing)	15/5	20/10	25/15	30/20	35/25	40/30	45/35	50/40	55/45	60/50	>65/55
LEED credits	1	2	3	4	5	6	7	8	9	10	11**

* Version 2.2 references an updated standard (ASHRAE 90.1-2004), and *reduces* the percentage savings required for each point. No building in the dataset for this paper used version 2.2, thus the percentages above are for versions 2.0 and 2.1.
** This eleventh point is given consistently by the USGBC as an "innovation" credit.

Simulated operational energy consumption is divided into two categories. "Regulated energy" consists of services that all commercial buildings share because of statutory building codes – space conditioning, ventilation, lighting, and hot water supply. The remaining consumption is "unregulated energy" (sometimes called "process loads" or "plug loads") that represents all tenant- or building-specific services such as computers, specialist equipment, lifts, and miscellaneous devices that use wall sockets. In LEED for New Construction versions 2.0 and 2.1 (which all buildings in this paper used), energy efficiency credits are given for regulated energy efficiency only. Unregulated demand was not required to be simulated. Consequently, energy consumption figures from LEED simulations are not intended to predict total building consumption without an assumption regarding unregulated energy.

Newer versions of LEED (beginning with 2.2), reference a new simulation methodology that requires unregulated energy to be considered. However, this does not require buildings to simulate unregulated energy demand. Those that do not can simply assume unregulated energy will make up 25% of total building energy. Unregulated energy consumption can thus be calculated as 33.3% of the regulated energy consumption model (resulting in a total building energy split of 75% regulated and 25% unregulated).

This assumption regarding unregulated energy was used in a study (Turner and Frankel 2008) that compares simulated energy consumption to measured energy consumption for LEED-certified buildings. Gross energy consumption of their entire population (N=121) of buildings met expectations of efficiency relative to the compliance baseline, but the distribution was highly scattered at the individual building level; over half the projects deviated more than 25% from expected consumption. Similarly high variability has been observed in buildings marketed as energy-efficient in the UK (Bordass et al. 2001) and New Zealand (Gabe 2008), with potential causes identified as the tendency to specify complex building systems in green buildings that are difficult to model and manage and poor understanding of unregulated energy consumption.

Newsham et al. (2009) applied more rigorous statistical analysis to the Turner and Frankel (2008) dataset, and concluded that there was a very weak relationship (r_{adj}^2=0.11) in the expected trend that an increase in LEED energy efficiency credits earned leads to a decrease in energy consumption costs post-occupancy. Their study also provided more rigour to Turner and Frankel's conclusion that, on average, LEED buildings performed better than "conventional" equivalents, but approximately one-third of LEED buildings consumed more energy than a non-LEED equivalent.

MODELLING

This study aims to understand the implications of observed resource consumption variability on the business case for green building – particularly the value of market signalling. Data on energy consumption variability of a sample of LEED-certified buildings (Turner and Frankel 2008) is used in two models of a hypothetical situation where the 11 credits awarded for simulated energy efficiency are adjusted for observed consumption variability. The dataset used in these models contains the first 450 LEED-certified buildings, of which data on credits earned were available for 448. Results are presented relative to the original distribution before adjustment (Figure 1).

On average, each building in the dataset earned 4.4 credits for proposed operational energy efficiency (out of a possible 11). The median was 4 credits. Fifty-eight buildings (13%) opted not to pursue any credits for operational energy efficiency.

Given the discussed methodological weaknesses of comparing simulated and measured energy performance, two models are produced to understand the implications of uncertainty in such results. The "advanced model" assumes that the variability observed by Turner and Frankel (2008), both in distribution and magnitude, is representative of the dataset. The "simple model" limits adjustments in energy efficiency scores to one credit. It represents a scenario where simulation improves (such as better modelling of unregulated loads).

Advanced Model

One dataset from the Turner and Frankel study (reproduced below as Figure 2) compares simulated and measured data from 71 "medium energy use" buildings. Data is presented in the metric used to award energy efficiency credits – proposed energy consumption relative to code compliance (see Table 1). Figure 2 contains buildings that would have gained zero optional energy efficiency credits, so this model for re-distribution of energy efficiency credits will include all of the first 450 LEED-certified buildings with credit data available (*N*=448).

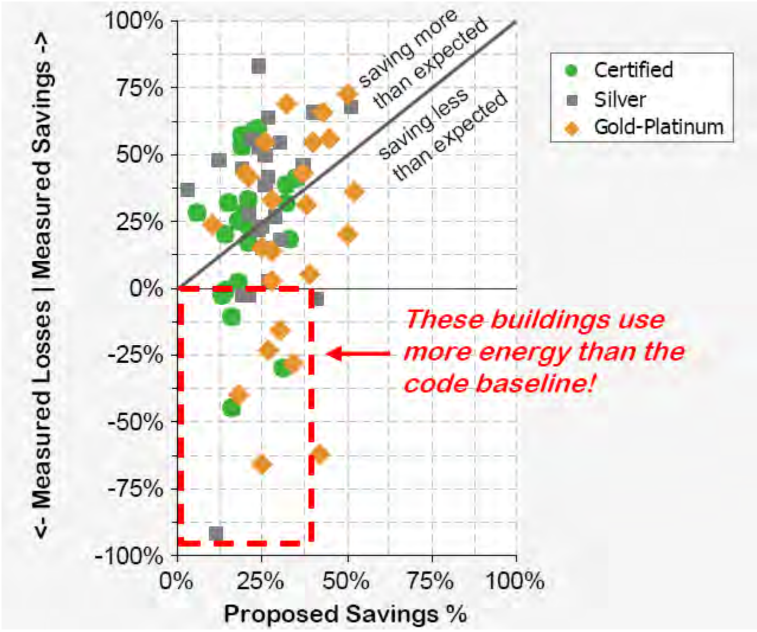

Fig. 2. Comparison between proposed (simulated) and measured energy savings (relative to ASHRAE 90.1-1999 standard). Source: Turner and Frankel (2008).

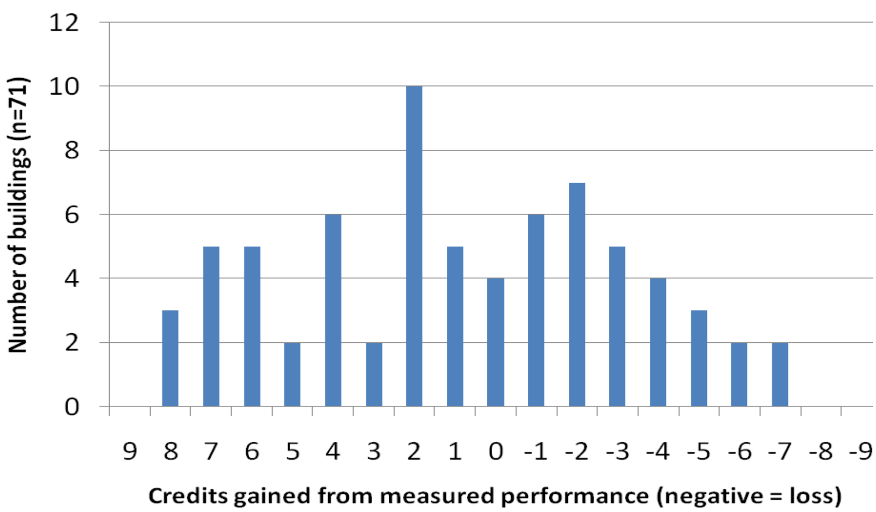

Fig. 3. Distribution of "credit differential" for the 71 buildings in the Turner and Frankel comparative dataset. Credit differential is the number of credits awarded from measured savings minus the credits awarded from proposed savings.

To model changes in energy efficiency credits, each of the 71 data points in Figure 2 is translated into a credit differential; this is defined as the total number of credits based on measured savings minus the number of credits based on proposed savings. Credits are awarded based on the thresholds in Table 1. To account for the discrepancy in credit thresholds between new and existing buildings, it is assumed that half of the buildings in the sample are new and half are existing buildings undergoing major renovation. As a result, the model calculates credit thresholds to be exactly in-between the new and existing building thresholds; for example, the model awards one credit for energy savings at 10% improvement relative to the baseline standard, two credits for 15% improvement, and so on. Publicly available data does not indicate whether a building qualified for LEED as a new building or existing building undergoing renovation.

A positive credit differential indicates actual savings were underestimated during design while a negative credit differential indicates actual savings were overestimated. The resulting distribution of credit differential is presented in Figure 3. The mean is 1.13 credits gained, median is 1 credit gained, and standard deviation is 3.92.

To use the distribution of credit differential in a re-calculation of the energy efficiency credits awarded pre-occupancy, the distribution in Figure 3 was assumed to be normal (with mean of 1.13 and standard deviation of 3.92). Each building was assigned a random number in this normal distribution by R, the statistical computing software. This random number was then rounded to the nearest integer, and represents the credits gained (if positive) or lost (if negative). Summing this value with the original number of credits obtained for energy efficiency represents the adjusted number of credits earned based on a hypothetical re-distribution informed by measured energy performance as represented by the findings in Turner and Frankel (2008).

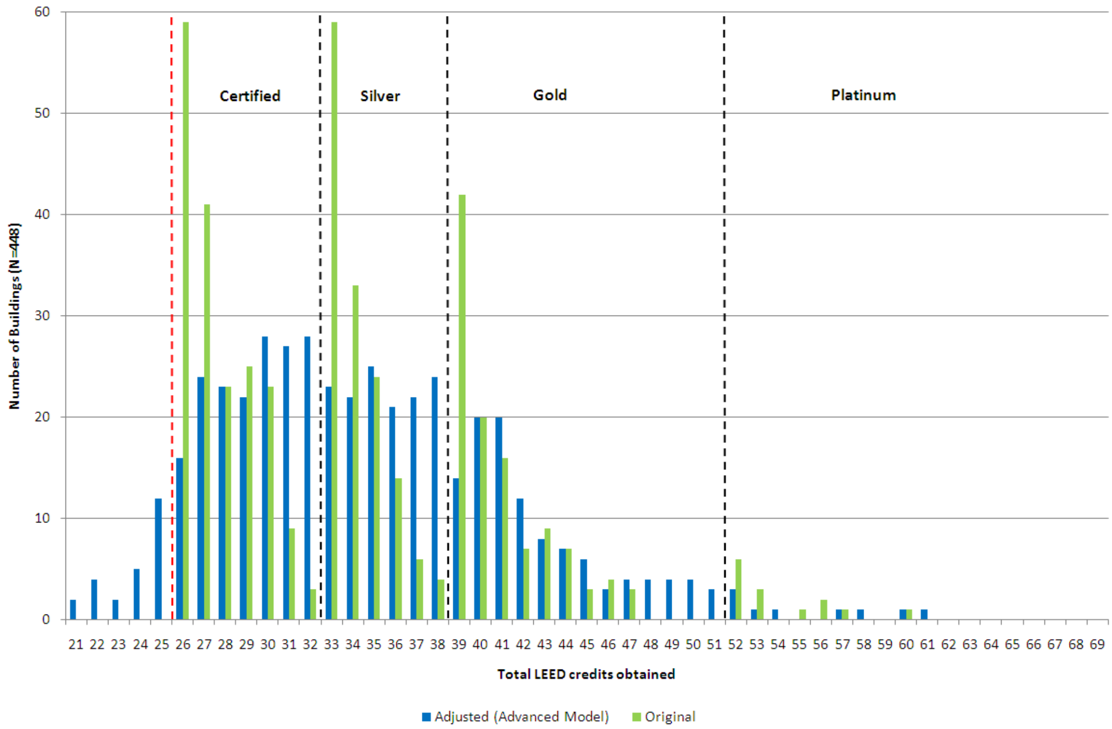

Fig. 4. Resulting distribution of total LEED credits obtained following the advanced model that adjusts proposed energy efficiency credits to measured energy efficiency credits.

The resulting re-distribution of total credits gained is presented alongside the original distribution as Figure 4. Dashed lines depict thresholds between distinct certification levels. A number of buildings fall below 26 credits and would hypothetically be subject to “losing” certification. In total, 94 buildings (21%) experience a demotion in their certification (25 of these lose certification, and 2 are demoted two thresholds, from Gold to Certified), while 46 buildings (10%) are promoted to the next threshold (none are promoted two thresholds). Only 69 buildings (15%) experience no change in their energy efficiency credits.

More buildings gain credits than lose them (median credit differential was 1) because there is more capacity to gain credits. Four buildings are hypothetically eligible to earn more than 11 credits (assuming the 12th credit is awarded at 65% savings) while 15 buildings have their credit loss capped because they cannot lose more credits than they gained originally (these are buildings that exceed the baseline standard for energy efficiency). An event not considered in this model is the loss of certification (from any certification threshold) that would hypothetically result from failing to meet a LEED prerequisite of compliance with the minimum energy efficiency standard.

There are two key assumptions that should be noted. First, the source data in Figure 2 – which is only of “medium energy use” buildings – must be assumed to be a representative sample across all the building types represented in the first 450 LEED-certified buildings (which include “high energy use” buildings such as laboratories or hospitals). Second, the model accepts the assumption made by Turner and Frankel regarding unregulated energy demand; the expected regulated energy consumption for each building is inflated by 33% to account for unregulated energy demand equal to 25% of total building energy consumption. These assumptions reflect limitations in publicly available data to model accurately a re-distribution of energy efficiency credits. As such, this version of the advanced model must be seen as a work in progress.

Energy savings in use may be slightly overestimated. Turner and Frankel (2008) observed high energy use buildings are more likely than medium energy use buildings to consume more energy than expected. Since the model applies a relationship derived from medium energy use buildings to all buildings, the set of high energy use buildings amongst the first 450 LEED-certified buildings are likely to have their energy savings in-use overestimated. In addition, the assumption regarding unregulated energy consumption may also overestimate energy savings. In an appendix, Turner and Frankel discuss an earlier (unpublished) study they conducted on energy modelling and found that when buildings did simulate unregulated energy consumption, the median percentage was below 15% of total building energy (compared with the standard assumption of 25%). The authors claim that using a lower percentage than 25% would not change the overall conclusions of their study (Turner and Frankel 2008: 41), but the standard assumption may effect an overestimate of energy savings when using their dataset to re-distribute energy efficiency credits. Figure 5 shows the potential “loss” of energy savings if lower percentages of unregulated energy are assumed.

For example, if a building measures 24% energy savings relative to a simulated baseline that assumes 25% of total building energy is unregulated energy, this improvement reduces to an energy savings of 14% if the simulated baseline assumes 15% of total building energy is unregulated energy. More accurate data may thus lead to fewer credits awarded when measured energy consumption is used in place of simulations.

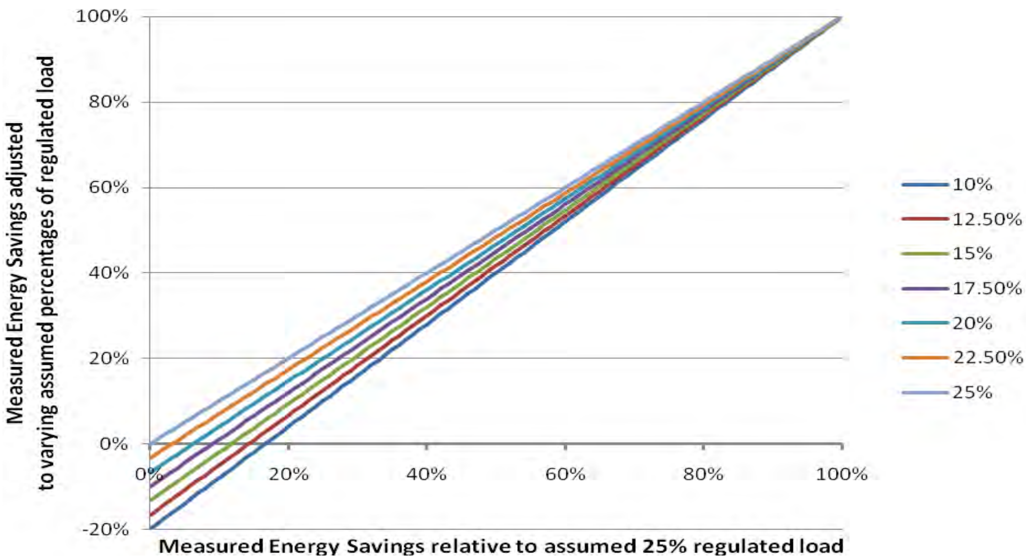

Fig. 5. Potential error in estimating measured energy savings that results from different assumptions for unregulated energy consumption as a percentage of total building energy consumption

Simple Model

This model is informed only by the finding that buildings were just as likely to outperform their simulated energy efficiency estimate as they were to underperform it (hence, on average, the entire population of buildings meets expectations). It does not attempt to take into account the magnitude of variance away from expectations, assuming that improvements in simulation (or adjustments to LEED criteria) can limit variance to one credit.

Only the 390 buildings in the dataset that obtained points for energy efficiency are included; the 58 buildings that did not attempt points are excluded from adjustment, with no change to total credits earned. By assuming a maximum variance of one credit, this model effectively limits the variance between proposed and measured energy efficiency to +/- 5% energy savings relative to the baseline. To stay consistent with using the median between credit thresholds for new and existing buildings as the modelling threshold, a minimum of 10% energy savings is needed for one credit.

One-third of the point-earning buildings is assumed to gain one credit as a result of exceeding expectations of energy efficiency, another third is assumed to lose one credit as a result of underperforming expectations, and the final third is assumed to have no change. To randomly apply these adjustments, the 390 buildings were arranged by the USGBC "project number" (given to a building when they register interest in certification). In the resulting list, buildings 1, 4, 7, and so on gain one credit, buildings 2, 5, 8, and so on lose one credit, and the remaining buildings are left unchanged. Six buildings in the dataset obtained all 11 credits for energy efficiency and are ineligible to gain another credit, so no change in total credits was assumed if one of these buildings was assigned to the group that gained one credit (this affected two buildings and was inconsequential to any conclusions drawn since that one credit would not affect their certification level).

The resulting re-distribution of total credits is presented, alongside the original distribution, as Figure 6. Dashed lines depict the thresholds between distinct certification levels. Since some buildings that obtained 26 credits (the minimum required for certification) are expected to lose one credit, those buildings would hypothetically be subject to "losing" certification. In total, 61 buildings (13.6%) experience a demotion in their certification (19 of these lose certification), while only 3 buildings (0.7%) are promoted to the next threshold.

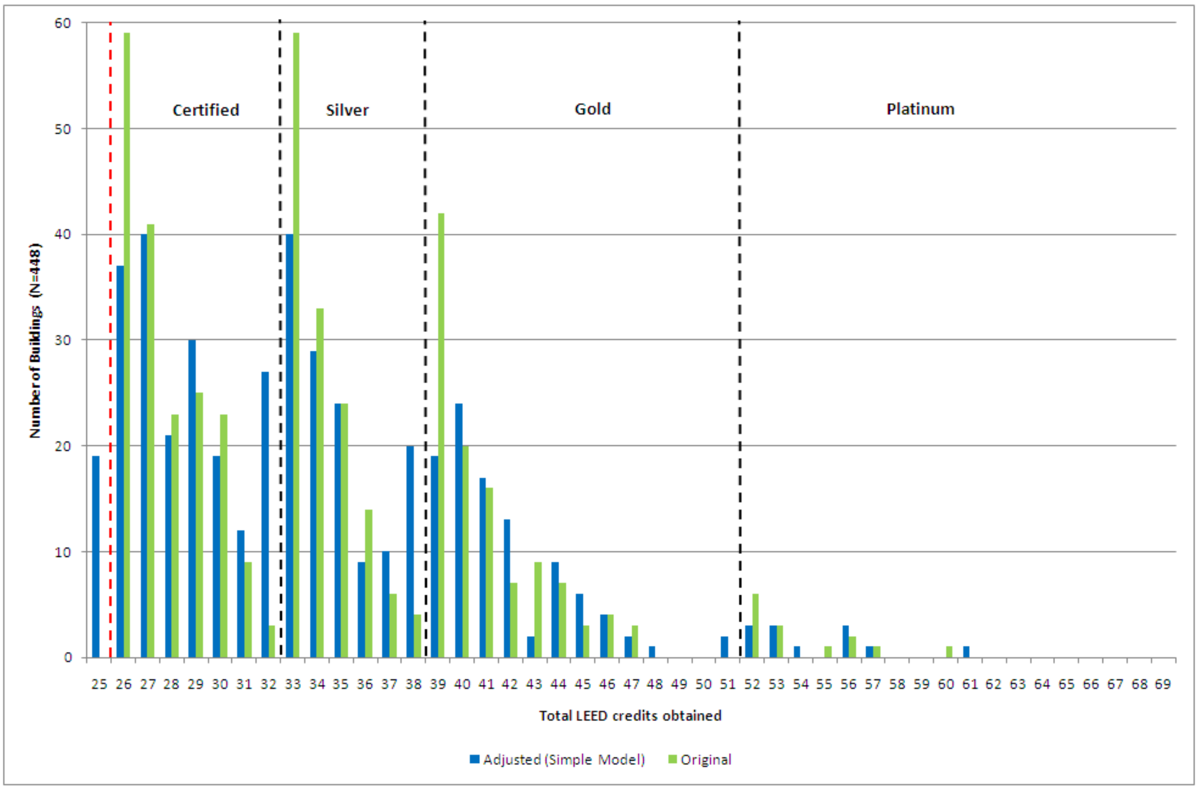

Fig. 6. Resulting distribution of total LEED credits obtained following the simple model that adjusts proposed energy efficiency credits to measured energy efficiency credits.

DISCUSSION

This study shows that one key component of green building certification – measured operational energy efficiency – is difficult to predict pre-occupancy to the precision that LEED certification awards optional credits. Post-occupancy comparisons between measured and predicted energy consumption are highly variable; the advanced model that attempts to account for the magnitude of observed variability finds that only 15% of buildings perform within the range of energy savings predicted by their energy efficiency credits.

As a result of the weight given to energy efficiency, approximately one-third of certified buildings are misrepresented in the market. The advanced model shows that one in every 5 LEED buildings is certified at a higher level than it performs, while one in every 10 would qualify for an increase in certification level. The actual number of misrepresented buildings may be higher if building water consumption projections – another core part of green building certification – show similar variability, or if the hypothesised overestimate of energy savings in the advanced model is confirmed. One result could be decreasing price premiums as tenants (who may place higher value on intrinsic benefits relative to market signalling) become aware of uncertainty in the expected link between certification signals and performance.

Although these models examined LEED certification, which is predominantly used in North America, the findings are applicable to Australasia because local certification tools use similarly precise thresholds for awarding energy efficiency points. New Zealand's Green Star certification tool awards an optional credit for each 5% of predicted energy savings above a baseline figure of regulated energy consumption (identical to LEED). The current version of Green Star in Australia uses an even more precise threshold, awarding a credit for every 4.5% improvement in energy consumption-related greenhouse gas emissions against a baseline figure. One key difference between Australasian certification schemes and LEED version 2 is that Green Star has more total optional points (144 and 151 for Australia and New Zealand respectively) than LEED (69). The appearance of a greater weight for energy efficiency in LEED is largely offset by Australasian systems allowing a building to gain up to 23 points[1] from operational energy efficiency (compared with a LEED maximum of 11), and further offset by the Australasian practice of declaring some optional credits “not applicable” to a particular building. Credits declared “not applicable” are removed from the certification process. The 23 energy efficiency credits are always applicable, so any difference in weight given to energy efficiency between LEED and Green Star is expected to be marginal.

An often suggested improvement to green building certification at the design and as-built phase is to improve the accuracy of energy consumption modelling. The simple model, which constrains variability to one point and has a far greater percentage of buildings experiencing no change, can be used to hypothesise the effects of this change. Misrepresentation does decrease, but by much less than one might expect given the relatively large decrease in variability. With the maximum gain or loss constrained to one point, misrepresentation is only cut to 14% - just under half the total number of buildings misrepresented in the advanced model.

A gap between modelling accuracy and credit thresholds can thus explain some of the misrepresentation, but not all. The other cause is likely be the primacy of market signalling as an incentive to pursue green building certification. Although LEED thresholds are arbitrary, many users aim for outcomes at (or only slightly above) minimum requirements (Corbett and Muthulingam 2007; Gabe 2010). This behaviour exposes the building to the risk that the loss of a single credit is likely to result in the building falling below its certification threshold. The simple model, where variability is constrained to one point, is a good example of this risk; of the 64 misrepresented buildings, nearly all (61) would have their certification demoted (or removed). Even in the advanced model, where, on average, a building gains one point, there are more demotions (94) than promotions (46).

OPPORTUNITIES FOR INNOVATION

Green building councils are interested in innovation towards long-term building performance outcomes as well as provision of credible differentiation labels. This study reveals that, though the latter is likely to be a stronger driver in the current market, market differentiation presents a risk to credibility. There appears presently to be a conflict of interest between users of design and as-built tools and those seeking improved performance. An opportunity exists for green building councils to use green building differentiation in a strategic manner to leverage innovative behaviour towards maximum performance outcomes to mitigate this conflict.

One possible strategy is providing less certainty about perpetual certification by renewing design and as-built assessments with performance measurements. To minimise the additional burdens of re-certification, perhaps only credits based on operational resource consumption would be re-assessed. This places green building assessment in-line with financial assessment, where a business plan (or prospectus) is followed up by reporting of actual results to the market using accepted accounting principles. Figure 1 can be seen as an aggregation of business plans, while modelling results (Figures 4 and 6) are attempts to simulate the performance of these business plans.

In a scenario involving ongoing performance adjustments, it may be optimal for design teams to pursue an insurance strategy (exceeding the minimum credits as a means to mitigate the risk of underperformance) in order to maintain certainty on differentiation. This creates a more efficient market for consumers because design-stage certified buildings are likely to maintain its chosen level of

[1] This includes 3 optional points for lighting efficiency and 20 optional points for all other regulated energy loads. LEED includes lighting in the overall building regulated energy simulation.

differentiation even if they are in the set of buildings that underperforms in operation. Concern towards "misdirected attention" at credit definitions, rather than innovation (Hoffmann and Henn 2008), could also be reduced. Another positive side-effect of performance assessment is an incentive for increased communication between building design teams and end-users – an often-suggested solution to variable performance outcomes (Bordass et al. 2001; Gabe 2008).

As for the conflict of interest between building owners and tenants, less certainty of perpetual certification increases risk to owners (who may lose certification or face demotion), but may ultimately be to their benefit. As the advanced model shows, buildings, on average *gained* one point. Although this gain may be an artefact of poor assumptions for simulating unregulated energy demand, the possibility of future advancement can incentivise ongoing improvements. Facilities managers are often looking to reduce energy and water costs and the reward of additional certification credits may make future investments in resource efficiency more attractive.

Most green building councils do have a strategic vision for performance assessment, but performance-based certification has consistently been developed later than design and as-built assessment. The first potential set of accounting principles and methodologies for rating the ongoing performance of these buildings, the LEED for Existing Buildings: Operations and Maintenance tool, was only introduced in 2008 –eight years after LEED for New Construction was first available. Neither New Zealand nor Australia has yet introduced an equivalent performance-based tool; though the Australian market does have an opportunity to integrate NABERS with Green Star (the tools are separately administered).

CONCLUSION

Through two models of re-allocating credits for energy efficiency performance in LEED-certified new buildings, market behaviour and optimism with the precision of contemporary energy consumption simulation were shown to contribute to the potential misrepresentation of up to one-third of certified buildings. This introduces a conflict of interest between building owners and those who value building performance. Eliminating this conflict is one of multiple benefits that are likely to result from a change in certification process that involves a level of ongoing performance assessment.

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