The Role of Quantitative Data in Defining Success: A Tale of Two Green Academic Buildings

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ABSTRACT

This paper investigates two "green" academic buildings: the Environmental Technology Center (ETC) at Sonoma State University and the Adam Joseph Lewis Center (AJLC) at Oberlin College. Both are designed to demonstrate sustainable architecture and to be used as teaching tools. Both employ passive and active systems to achieve these goals. Our analysis of these buildings focuses on the presence, absence, and use of quantitative data in defining their physical "success." The presence and subsequent interpretation of monitored data in the AJLC has created controversy; the absence of these data in the ETC *could* have created administrative controversy but has not. Even without quantitative proof, the ETC has been judged empirically successful by local users. Although some interpretations of the quantitative data say otherwise, the AJLC continues to be treated as an icon of sustainability by many non-local sources.

Introduction

In an ideal world, a successful sustainable building would work well in both theory and practice. It would also concurrently deliver easily decipherable monitored data to prove its claims. In the real world, however, determining the "success" of a building, particularly from monitored data, is not a simple endeavor with a binary outcome. To explore the lessons learned from specific architectures in particular places, we investigate two "green" academic buildings: the Environmental Technology Center (ETC) at Sonoma State University and the Adam Joseph Lewis Center (AJLC) at Oberlin College. These buildings were designed to be far better than average, but by what measure are they better? Are there ways in which they are worse? Despite much public critical acclaim, people involved with both buildings are frequently called upon to prove that the pedagogical, architectural, and environmental theories behind them are working in practice. Elsewhere, we have considered the influence of accounting practices, technology adoption, and pedagogical goals on these two buildings (Janda & von Meier 2005). In this paper, we focus on the presence, absence, and use of "data" as a lens through which to consider building performance.

To most laypeople, understanding building performance is more difficult than, say, understanding automobile performance. Benchmarks for automobile performance are widely publicized and fairly well-understood by the general public. For instance, everyone of driving age in the US knows that "15 miles per gallon" is not a "good" number. Even here, however, standards of performance have cultural underpinnings. If this relationship was expressed as 16.7 litres per 100 km the understanding of "goodness" would vanish for a US audience and materialize for European readers. Moreover, standardization of a performance indicator based solely on distance travelled per volume of fuel may obscure other significant sustainability criteria (e.g., emissions). Although quantitative measurements seem to deliver "hard" numbers about intrinsic levels of performance, these levels are themselves socially constructed and understood. To understand how a building functions, then, we cannot consider quantitative measures in isolation; rather, we derive meaning by considering them in context with qualitative performance dimensions.

In this paper, we consider the physical performance of "green" educational buildings through two interrelated dimensions: quantitative measures and direct experience. As we will show, these dimensions frame different understandings of success or failure in energy use, thermal comfort, and concept demonstration. We begin with a brief description of both buildings to situate the reader.

Building Descriptions

The ETC at Sonoma State University (SSU) is a 2,200 square foot building with one large seminar room that functions as an auditorium, classroom, and laboratory. Funded in part by National Science Foundation and California Energy Commission grants and completed in 2001, the ETC was conceived as a "building that teaches" (Rohwedder 1998), offering an immediate hands-on experience of high-efficiency technology and green building to general audiences as well as an abundance of real-time data for building science buffs. Use of the ETC comprises university classes and educational events involving outside agencies and the general public. The ETC has also become a favorite classroom for two other uses: a yoga class and *a capella* singers. The ETC was the subject of Congressional testimony before the House Energy Subcommittee (von Meier 2001), and it also hosted a field hearing, serving as a concrete example of the concepts of energy efficiency and renewable resource use (US House of Representatives 2002).

The ETC is widely experienced as a success, especially with regard to its outstanding thermal performance. Here the simplest of passive solar design strategies–daylighting and incorporation of ample thermal mass–turned out to be the big winners, both in terms of energy savings and, perhaps even more importantly, occupant comfort. Perhaps the most remarkable success is that the ETC maintains pleasant indoor temperatures during summer heat waves without any active cooling whatsoever. Combined with interesting materials, angles and aesthetics, the experience of comfort seems to leave occupants and visitors with an overwhelmingly positive impression and inspiration.

Like the ETC, the Adam Joseph Lewis Center for Environmental Studies at Oberlin College serves many purposes. The AJLC is a two story 13,600 square foot building with three classrooms, a library, an auditorium, six offices, a conference room, and a kitchen. It also houses a "Living Machine" that treats and internally recycles wastewater from within the building. Like the ETC, it was designed as a building that teaches. In the words of David Orr, the chair of Oberlin's Environmental Studies Program, the project team wanted a building that would "help redefine the relationship between humankind and the environment - one that would expand our sense of ecological possibilities" (Reis 2000).

The AJLC has enjoyed considerable critical acclaim. It has received architectural awards from the American Institute of Architects, construction awards from national and state contractors organizations, an Ohio governor's award for energy efficiency, and been named one of the thirty "Milestone Buildings for the Twentieth Century" by the US Department of Energy. An early model of the building is included in an architectural textbook on the interactive effects of buildings and the environment (Fitch & Bobenhausen 1999: 336), a diagram appears in a popular environmental science textbook (Miller 2001: 537), and it has been the subject of numerous articles in the press. Part of its notoriety has to do with its star architectural team, William McDonough + Partners, which is famous for several sustainable buildings as well as a book on the topic of sustainability (McDonough & Braungart 2002). Part also has to do with the dedication and eloquence of its on-campus champion, David Orr, who is a prolific writer, a dynamic speaker, and has published several articles about the AJLC's design process (Orr 2002, 2003a, 2003b).

We believe the stories surrounding these two buildings–including the range of perspectives on how "efficient" or "consumptive" they are, as well as how their performance is accounted for and by whom–has much to say about how expectations for building performance are shaped and understood by different audiences. In particular, we consider how local and non-local audiences experience both buildings.

Performance by Numbers

Quantitative measures of building performance include all such things as can be expressed in numbers. Construction cost, temperature, humidity, air changes per hour, light levels and energy consumption obviously fall in this category, as do less frequently cited variables like embodied energy in building materials, water use, or noise level. As we shall argue in this paper, the use of quantitative measures, while they may afford scientific reproducibility or "hard data," is fraught with important caveats when evaluating overall building performance. In this section, we describe several types of problems with defining a baseline for comparison, then give specific examples of how such problems complicate assessments of the ETC and AJLC.

Compared to What?

The key question when trying to cull scientific meaning from any numerical datum is, Compared to what? In evaluating building performance, there are essentially three possibilities: We may compare the building in question (a) to other buildings of its type; (b) to a set of prior expectations or projections about this particular building; or (c) to itself over time. Whether a building might be considered a "success" or "failure" depends first of all on which of these comparisons is invoked. Even when the basis for comparison is clear and explicit, it may not be unproblematic.

Comparable buildings. In case (a), a "comparable" or average building may be assigned on the basis of square footage, use category, and climate zone. While this is easy to do for residential or standard commercial structures, there are to date but a handful of extant "green" educational buildings, each with unique characteristics. We might compare the ETC and ALJC to each other, or to conventional university buildings that house classrooms, offices, and laboratories on a per square foot basis; nevertheless, each is unique in its design intent and allocation of space. There is simply not a sufficiently large sample of sufficiently similar buildings to draw conclusions about building performance from statistical comparisons without qualifying remarks.

Expectations. In the case of (b), expectations and projections may be explicit or implicit. On the one hand, quantitative predictions such as those produced by computer models readily lend themselves to comparisons with quantitative measurements of the finished building. On the other hand, much of what is expected from a building in progress may go unrecorded, assumed perhaps to be obvious. Then the question is, whose expectations make the best basis for comparison — owner, architect, or contractor? Analyst, funding agency, or casual visitor? Furthermore, the as-built structure may diverge from the original plans; indeed, it would seem unrealistic to expect a unique and deliberately non-standard project not to undergo some modifications during construction. But performance projections were most likely based on the original design. To which expectation should the finished building be compared now?

Over time. Finally, with (c) we recognize that building performance may change over time. Longevity and durability matter, yet these qualities cannot be captured by a single snapshot in time. Improvements, retrofits, and usage changes all affect building performance, so snapshots of building performance at different times will present different images.

All of the above factors force the conclusion that evaluating the performance of any building, and especially a unique building with multiple missions and multiple stakeholders, is not a straightforward task.

If qualitative impressions of building performance seem subjective and unscientific as evaluation tools, a case can be made that quantitative measurements may, too, be just that. Guy and Shove (2000) argue that "epistemic regimes" tend to bracket knowledge in ways that prop up their own authority. One way of doing that is simply to discount different forms of knowledge as legitimate. At issue here are not likes and dislikes, but divergent definitions of what quantitative measures constitute desirable performance and how these data are to be obtained. We use monitored infiltration rates and expectations about energy use to illustrate how divergent and subjective definitions affect assessments of the ETC and AJLC.

Infiltration in the ETC

One paradigmatic example of divergent definitions of performance in the ETC was the issue of air infiltration rates. The architect had specified the building to allow 0.2 air changes per hour (ach), which to him and the design team represented an ambitious but plausible goal for a state-of-the-art, airtight commercial building. The builders, on the other hand, considered this figure to be idealistic and unattainable in practice. Achieving such low infiltration rates would have required an uncommon level of attention during the early construction phase, scrutinizing every crack and crevice in walls, floor, and ceiling for possible air leakage. From the architect's perspective, it seemed realistic to expect the contractor to exercise such care, as the building envelope represents an integral component of the building's final energy performance. From the contractor's perspective, "airtightness" was not a familiar performance criterion for structural elements, which were understood to count for mechanical strength and R-value on a macro rather than a micro scale. It is easy to imagine how, to the workers on the construction site, the architect's concern about air coming through nail holes (let alone all the fuss over the multiple, ultra-tight window latches) would have seemed rather silly if not downright obsessive.

When it came time for the blower door test, the design team was disappointed by the results, which initially were above 1 ach. But the fascinating thing is what happened next: In an effort to reconcile data with expectations, the contractor undertook a special preparation of the building for a second blower door test. Workers spent an entire day covering all visible orifices, from door handle joints to electrical outlets, in blue masking tape. The new and improved ETC measured 0.5 ach - still not meeting the original specifications, but a number that would be considered decent for a commercial building and ultimately represent an acceptable compromise.

During this process, with all parties anxious to finally complete a behind-schedule, over-budget project in reasonably collegial spirits, nobody (including one of the authors) dared call attention to the obvious disconnect between the data measured (the infiltration rate of the taped-up building) and the building's actual performance when occupied (which certainly does not involve masking tape). The measured air change figure became a legal entity rather than a physical datum. It was the number of record that could be pointed to in judging success or failure, crediting diligence or assigning blame, yet it had very little to do with the finished building's air circulation, its energy consumption, or the comfort experienced by its occupants.

It turns out that, owing to the other insulating and thermal storage techniques, the building seems hardly affected by the greater-than-specified air infiltration. During its first two heating seasons, the hydronic floor active heating system has only been operated sparingly on the few days when passive solar gains were insufficient for occupant comfort - totaling less than a dozen or so days per year. Thus, while infiltration rates certainly affect the efficiency of space heating, the ultimate impact on annual energy use is small due to the small amount of heating energy used to begin with. Of course, heat losses from infiltration also affect the building temperature on passive heating days, and might conceivably result in active heating to be used on some days when, without the excess infiltration, it could be avoided. This scenario has not been modelled quantitatively. However, the actual number of active heating days suggests an upper bound for the total heating energy impact. If one assumed generously that 10 per cent of heat losses were attributable to excess infiltration, this would imply no more than about one day's worth of heating energy consumed per year as a result. (Note that, on passive heating days with sufficient solar gains, the heat flows resulting from unplanned infiltration are not countable as "losses" because given that occupants are comfortable with the temperature as it is, they would presumably begin to open windows if the building were any warmer).

Since there is no active cooling, warm air infiltration in the summer has no impact on energy consumption. Even though greater airtightness would undoubtedly allow the building to stay even cooler during hot days, this hypothetical comparison is not one that presents itself to occupants. Rather, the operative standard would be other campus buildings, and here the ETC compares rather favourably. When other classrooms are cooled to 68°F (20ºC), the temperatures around 70°F (21ºC) in the ETC on hot summer days appear quite similar - especially subjectively, after walking through sweltering heat to reach the building. Indeed, after the California electricity crisis in the summer of 2001, when the Chancellor ordered thermostats in all California State University buildings reset to 78°F (26ºC), the ETC became literally the coolest building on campus (prompting SSU President Armiñana to quip that it was no doubt in violation of the Chancellor's directive).

Expectations of Energy Use in the AJLC

There are two ways in which quantitative measures of energy use have been contested in the AJLC. The first has to do with the relationship between energy use and energy production; the second involves assessments of energy intensity.

An early design intent associated the AJLC was that the photovoltaic array on the roof would produce more energy than the building consumes. There are several different ways in which this intent has been interpreted. The strongest version of this claim is that the AJLC would be a "net energy exporter" on an annual basis (Gabrielli 1995). A second version reports that the building will be a net energy exporter "at times." (Fitch & Bobenhausen 1999: 336) A third interpretation is that the building will "evolve into" a net energy exporter (McDonough 2004). Audiences expecting the strong version of the design intent to manifest in practice have been disappointed to learn that the AJLC is not currently a net annual energy exporter. However, the second version of the claim is true. On sunny summer days when the air conditioning is not running, the building does produce more energy than it consumes. Whether or not the AJLC will *eventually* become a net annual energy exporter, as the third interpretation suggests, remains to be seen. This version of success depends partly upon further reductions in annual energy use and partly upon replacing the existing 60 kw rooftop photovoltaic array with more efficient solar cells which will (theoretically) be available in the future.

To monitor and assess precisely these kinds of issues, the AJLC is overflowing with monitored data. Funded in part by a grant from the Andrew W. Mellon Foundation and installed in collaboration with the National Renewable Energy Laboratory, there are 148 data points that collect data on the flow of energy and matter through the building and its landscape (Petersen 2002). These sensors collect data on a minute-to-minute basis, and their real-time reflection of the relationship between the building and the environment is posted on the web and displayed in the atrium lobby (see http://www.oberlin.edu/ajlc). These data and the graphs they create provide a quantitative frame through which to view the AJLC's contribution to environmental problem-solving.

What is interesting about these data is that they seem to create more controversy than they resolve. In addition to the data points monitored by the Environmental Studies Program faculty, there are additional data available through a separate energy monitoring system and tabulated by a faculty member in physics. The raw data collected by the sensors are not disputed. However, there has been some disagreement regarding the interpretation. Depending on the time period chosen to analyze and the context selected for analysis, the AJLC uses either more or less energy than its peers.

In terms of its site energy, Petersen (2002) shows that the AJLC's gross energy consumption between April 2001 and April 2002 was 30,000 Btu per square foot. Compared to a national average reported for educational buildings, this is roughly 62 per cent better than normal. Compared to nine other buildings on Oberlin's campus, the AJLC's energy performance is 64 per cent better. When the production of energy produced by the AJLC's extensive PV array is included, its net energy consumption is just 14,000 Btus per square foot. This figure suggests that the AJLC imports only 17 per cent of the average energy consumed by Oberlin's other buildings.

While these numbers seem definitive, Scofield (2002a, 2002b, 2002c) uses the same data sources to paint a different picture. Instead of focusing on the amount of power generated by the PV array, for instance, it is possible to look at the differences between actual generation and projected energy output. From this perspective, Scofield shows that total energy production from the AJLC's PV array for 2001 was 15% below projections. This kind of deficit is typical for PV arrays, yet it affects the AJLC's ability to meet its annual load without assistance from the grid. In terms of energy consumption, Scofield uses data from January 2000 to December 2001 to show that the building used 48,000 Btu per square foot. Using this number as a basis of comparison, the AJLC's gross energy use is only about 37% better than the average educational building in Ohio's climate. Moreover, Scofield argues that a better basis for comparison should be source energy consumption, not site energy consumption. Because the AJLC is all-electric, any electricity not produced with its own PV array is most likely generated by burning coal in a local power plant. This process is only about 33% efficient, which means that the source energy requirements of the AJLC are 144,000 Btu per square foot—11% to 17% greater than comparable buildings. Because the AJLC does not meet its entire annual energy budget with its own PV array, Scofield suggests that the as-built AJLC may have been "greener" if it was not all-electric.

If the AJLC "succeeds" according to one quantitative analysis and "fails" according to another, what are readers of either or both analyses to make of these interpretations? To some degree, the difference between these assessments stems from koan-like questions about whether it is better to see the glass as half-full or half-empty. Both Petersen and Scofield assess the AJLC's performance over time, but their analyses use different time periods. Scofield uses data from the building's initial operation; Petersen uses data from a later period. If buildings have a learning curve, the part of the curve selected for analysis inevitably influences the results of the assessment, as does the basis for comparison. Unable to reconcile differences between these viewpoints, what many people on the Oberlin College campus take away from this debate is that the AJLC just plain "doesn't work."

Quantitative data are often expected to provide "proof" that somehow exceeds qualitative impressions, but in our view they may raise more questions about building performance than they resolve. Such questions should be considered as opportunities rather than challenges, particularly in an academic environment where the exploration of objective and normative truths should be fair game. These examples demonstrate how quantitative data have been used to influence socially constructed concepts (such as what constitutes "success") while maintaining an aura of objectivity.

Performance through Experience

Direct experience is another powerful determinant of building success, particularly on college campuses where students and faculty frequently visit buildings other than their own for classes and meetings. Although even harder to objectively assess than quantitative measures of building performance, direct experience seems to trump quantitative data as a performance indicator. Direct experience is accrued whenever someone—be they visitor or regular inhabitant—physically enters a building. For instance, it includes physical comfort along with the entire spectrum of mental and emotional impressions one carries away from spending time in a building. It involves, for example, feeling warm or cold; confined or open; aesthetically attracted or not attracted; bored or inspired. Direct experience is also associated with the demonstration of green design concepts: seeing that something can be done, or *how* it can be done, in order to achieve a certain objective. For the most part, this would include demonstrating particular design elements—say, various types of shading devices, or an innovative concrete mix—proving that their use was feasible (to the extent that they could actually be built) and illustrating how such elements appear within the building context. It could also mean demonstrating scientific concepts, such as radiant heat transfer, by having design elements accessible and transparent.

Thermal Comfort and Concept Demonstration: ETC

Because of initial difficulties with the building management system (BMS), energy information for occupants and visitors to the ETC has been largely limited to their immediate experience through the senses, rather than figures or graphs from a computer. Aside from the building's net electric meter, which dramatically illustrates the effect of solar generation by spinning backwards, energy generation and consumption data are not readily accessible to the visiting public in visually compelling trend logs or real-time displays. Nevertheless, ETC visitors are generally content with qualitative information through their own impressions (combined with the director's vigorous oral assertions on the subject). Thermal comfort, air quality, and lighting are obviously key factors; what also gets noticed are the seminar room's problematic acoustics on the one hand and the pleasant absence of operating noises on the other.

Interestingly, qualitative impressions rather than quantitative "hard" data seem to be what most visitors want to get from the ETC, anyway. One obvious reason is that the great majority of visitors are lay persons with regard to building energy analysis. With the exception of a number of building professionals and a handful of scientists who frequent the ETC, most builders and members of the general public alike have little mental framework with which to integrate quantitative building performance data. The number of air changes or the Btu consumption for heating can actually be less meaningful than the qualitative impression that "the air smells fresh but it doesn't feel drafty," or "it's nice and cool in here on a hot summer day."

A second reason why the paucity of quantitative data at the ETC may not be seen as unfortunate even by building professionals is that the qualitative information tends to be more generalizable. Most visitors care less about the performance of the ETC *per se* than about the possibilities for applying certain of the ETC design concepts elsewhere, whether in their own home, their professional construction work, or even the building codes they recommend and implement as public officials. While numerical data would have served to support qualitative statements such as "the Trombe wall supplies heat to the office space after sunset" or "the clerestory dramatically reduces the need for electric lighting," the quantitative measures themselves would not be transferable to any other building, where all the parameters from floor plan to incident sunshine will, of course, be different. For example, no reasonable person would extrapolate that a clerestory will save their building x number of kilowatt-hours per year just because it does so in the ETC. The key information being communicated, rather, consists of the *ideas* for employing certain design elements, *examples* of their execution in a particular setting, and their *perceptible function* in terms of sensory impressions (heat, light, sound, smell, touch, sense of space) and aesthetics. Thus, what a typical visitor would want to take home with them is not a measurement of how many Btus per hour are coming through the ETC's Trombe wall, but the thought that "I'll see about including a Trombe wall in my new house, because the one at the ETC felt very nice." This finding is consistent with the phenomenological understanding of intentionality in design: we intend material experiences, not abstract expressions like Btu per square foot per year.

Thermal Comfort and Concept Demonstration: AJLC

In contrast to the ETC, the AJLC has had a checkered experience with thermal comfort. Despite complicated building schedules designed to minimize energy use, matching thermal comfort with building occupancy has proved a challenge during much of the heating and cooling seasons. The building is designed to take advantage of low-angle winter sun for passive solar heat, and it uses ground source heat pumps for supplementary heat. During the unusually cold winter of 2002-03, the AJLC's heat pumps did not deliver adequate make up heat. Due to the high thermal mass of the building, classrooms take a long time to heat up, and a longer time when the heat pumps deliver lower temperatures than design specifications. Discomfort in the building was so pronounced that at least one class scheduled to be held in the AJLC relocated to another building.

In the summer, high thermal mass and small diurnal temperature swings make it difficult to keep the AJLC's atrium cool. Additionally, the south and east façades of the atrium allow a large amount of solar gain into the building. William McDonough intended for these gains to be mitigated by external vine-covered trellises. But energy simulations conducted using the computer program DOE-2 could not prove that the trellises were cost-effective. Because the construction cost of the south trellis was higher than the energy savings it would deliver, the College chose a lower first cost alternative: planting trees. Trees, of course, grow somewhat slower than vines, and summer shading on the east and south side of the building is unlikely to manifest in practice for several more years.

Although the AJLC did not provide access to adequate temperatures, it does provide more than adequate access to daylight. A professor of Caribbean literature told one of the authors that she wished to keep her class in the AJLC, even if it was cold in the winter. She said, "You can't teach my subject without sunlight." This professor's comment shows that although the AJLC's passive heating strategy does not work thermally, for some occupants it still successfully serves an important experiential purpose.

Whereas the ETC validated the premise of passive cooling and heating to the SSU community, the AJLC has not provided a similar learning experience to Oberlin College. This comparison is technically askew, because the design challenge of providing adequate levels of thermal comfort in sunny, dry Northern California is not as difficult as providing them in snowy, humid Northeast Ohio. In other words, it would be unfair to expect an Ohio building to embody the message, "it's easy to do without air-conditioning or heat." Nevertheless, since neither the general public nor university administrators are trained to think in terms of degree days and wet bulb temperatures, the level of thermal comfort actually experienced in each building remains a key empirical standard by which performance is judged.

Summary and Conclusions

Buildings cannot behave as exemplars for all things at the same time. It is very unlikely, for instance, that a single structure will simultaneously be the easiest to measure, the simplest to manage, achieve the highest benefits, incur the lowest costs, and be as sustainable as possible. Our analysis shows that the AJLC and the ETC are both successful buildings, but in very different ways. The ETC, despite lacks in its infiltration rate and monitoring system, is empirically satisfying and thermally comfortable. Its proof is in the pudding, as they say. The AJLC, in its conception as a holistic entity integrated with the landscape and the Living Machine, has been both a source of campus debate and the recipient of national awards. The ETC is a great success in practice; currently, the AJLC remains a greater success in theory than in practice.

Non-local audiences for these (and other) buildings are necessarily limited in their understanding to a conceptual interpretation of secondary data. Although we have focused here on the use of quantitative data, the secondary data available for both these buildings also includes pictures and text. In contrast, local audiences have the opportunity to assess these buildings both directly (through firsthand experience) and conceptually (via the same channels as non-local audiences). On an instantaneous basis, we believe that audiences for both buildings trust their own senses more than secondary data.

In terms of defining success, quantitative measurements often seem to give the purest sense of intrinsic building performance. As we have shown, however, such measurements can be constructed in ways that affect their objectivity. Moreover, for the many people who have direct experience with both buildings, the presence, absence, or interpretation of the numbers matter less than their direct experience. Relative to other buildings, what role does the presence or absence of quantitative data play? The data certainly form an epistemological lens for formal debate and discussion as described above. But how does this lens interact with the phenomenological one used for most buildings? That is, does "performance by numbers" override performance through experience? On an instantaneous basis, we would have to say "no." Over time, however, different conclusions might be drawn.

As is common in expert debates, numbers rarely change our notions of what we already believe to be true. For instance, visitors to the AJLC itself or to the website can observe a computer display that shows graphically and in real time whether the building is producing more energy than it is consuming. As most tours are given during the day, the photovoltaic array often produces enough energy to show that the AJLC is a net energy exporter *at that moment*. If the tours were given at night, however, the "take away" image would be different. These data confirm what our senses would expect. If the graph said otherwise, visitors would expect something was wrong with the sensors. On a cumulative basis, however, the quantitative data provide information that our senses cannot effectively collect and analyze. Another graph on the website and in the atrium integrates building consumption and energy production information over time, showing the annual pattern of energy exports and imports. This graph displays information that the viewer could not intuit just by standing in the atrium.

The concept of building performance over time is foreign to lay people, difficult to understand, and one of the most important directions for continued work in the field.

Future Directions

In *Slaughterhouse Five*, Kurt Vonnegut (1969) explores the notion of being "unstuck in time." We suggest that the notion of time should be incorporated more explicitly into explorations of building evaluation and sustainability. In particular, what is the right period of time to use for a quantitative assessment? If understanding climatic responsiveness is a goal, at least one cycle of four seasons is required. But a building that is *expected* to change its performance over time complicates the selection of the "best" date to begin a time-series assessment. When, for instance, does the AJLC begin its "real" performance? For those actively engaged in measuring building performance, this question may be as scientifically and socially contentious as determining the precise moment of conception. For many building users, however, the simple notion that building performance is variable instead of constant is hard enough to grasp.

More generally, the very notion of being "sustainable" implies a projection in time: an assessment of what would happen if practices and processes in question were continued indefinitely into the future or at least for a time period much longer than conventional planning horizons. Any economic evaluation of sustainable building measures also relies on time as a key variable, since present costs are almost always compared to some form of future savings. Standard discounting techniques from finance, while suited to a narrow and literalist interpretation of cost-benefit analysis, offer little guidance in the way of estimating the overall value or benefit to society of undertaking sustainable building: who decides on the correct discount rate, and how, in the long run, does one weigh the interests of different generations who bear the costs and reap the benefits of today's decisions?

Given the inherent limitations of quantitative standards and performance measures, meaningful inclusion of a time dimension should prove a challenging and worthwhile endeavor. By contrast, in the area of phenomenological satisfaction, we require no conceptual innovation but patience. How will these buildings hold up, and how will people feel about them as they age? Only time will tell.

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