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Cognitive biases in energy decisions during the planning, design, and construction of commercial buildings in the United States: an analytical framework and research needs
Klotz

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Cognitive biases in energy decisions during the planning, design, and construction of commercial buildings in the United States: an analytical framework and research needs

Leidy Klotz

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Abstract Despite a national goal for every building to achieve net-zero energy by 2050 and despite exemplary projects proving the technical and economic feasibility of much better energy performance, commercial buildings in the USA today use more energy per square foot than they ever have. Decisions made during planning, design, and construction (delivery) of commercial buildings appear systematically irrational, not maximizing utility for designers, occupants, or society. In other fields, notably economics, improved understanding of cognitive biases like "loss aversion" and "anchoring" has helped to explain seemingly irrational decision making. Related work has examined these cognitive biases for energy decisions made in an occupied building. Less clear is the role these cognitive biases play in the high-impact, long-term energy decisions made during commercial building delivery. As an initial step towards addressing this gap in understanding, this paper outlines key energy decisions in commercial building delivery and shows how cognitive biases may impact these decisions. A suggested approach to study these biases, and to design policies that address them, is provided. By highlighting these potential cognitive biases, based on an understanding of the building delivery process, this paper aims to engage those with relevant expertise in the behavioral and social sciences to help address the decision making that is preventing progress towards improved energy performance in commercial buildings.

Keywords Buildings · Design · Construction · Cognitive bias · Irrationality

Introduction

Buildings in the USA are responsible for more energy use and CO_2 emissions than any other sector, including transportation (US Department of Energy 2007). Therefore, significantly improved energy performance of buildings is essential for plans to address interrelated energy and climate issues (American Physical Society 2008; Pacala & Socolow 2004). Legislation targets all commercial buildings for net-zero energy by 2050 (US Congress 2007), which requires research to help achieve this net-zero energy mandate (US National Science Board 2009).

Despite this need to significantly improve energy performance, the last quarter century of available data shows a 16% *increase* in energy use per square foot (intensity) in US commercial buildings (US

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Department of Energy U.S. Department of Energy 2008).[1] Every other major sector has reduced its energy intensity over this same period (US Department of Energy U.S. Department of Energy 2008). The current "green" building movement is not solving this problem: the average energy intensity for a sample of over 150 certified green buildings is *higher* than the average for the USA's existing commercial building stock (Turner & Frankel 2008; US Department of Energy U.S. Department of Energy 2008).[2]

The failure to improve commercial buildings' energy performance contrasts with technical realities, as exemplary case studies (Lewers 2008; Ferreira 2008) and a National Lab report (Griffith 2007) demonstrate the feasibility of net-zero energy. This failure also contrasts with economic realities, as effective use of proven strategies like passive conditioning and integrated design can yield improved energy performance at a first cost savings, *before* considering reduced energy bills (Matthiessen & Morris 2007).

Cognitive biases can help explain instances, like energy use in buildings, where technical and economic factors do not fully explain the outcomes of decisions. Cognitive biases distort information in humans' thought processes and, in many cases, can enable faster decisions. However, these biases can also contribute to errors in judgment and limit our capacity to find perfectly "rational" solutions (Kahneman et al. 1991). Rationality in decision making typically refers to optimizing utility. This often means maximizing profit, but other factors such as pleasure, ease of decision making, and security are also utility optimization considerations. Economic theory is based on this principle of utility optimization, but economic models now also account for cognitive biases (Camerer et al. 2003).

Research has examined how these cognitive biases influence building occupants' and building operators' energy decision making (Jaffe & Stavins 1994; Turrentine & Kurani 2007). However, these occupants and operators control only a portion of a building's energy use. Much of a building's energy performance is related to decisions made by stakeholders (e.g. architects, engineers, contractors) during planning, design, and construction, yet the influence of cognitive biases on these pre-occupancy decisions is underexplored (Gillingham et al. 2009).

Significance and aim

This paper's significance is in highlighting the opportunities to improve energy performance of commercial buildings by studying how cognitive biases impact key energy decisions made by stakeholders during building delivery (planning, design, and construction). These cognitive biases have been studied extensively for the actions of those occupying and operating buildings (Wilson and Dowlatabadi 2007). For example, understanding how cognitive biases impact an occupant's use of air-conditioning helps identify effective methods to encourage the most efficient and comfortable use of the air-conditioning. However, regardless of the occupant's personal choice, decisions made by professionals during delivery of the building about solar orientation and the building enclosure (e.g. types of walls, windows, roofs), for example, also have a large impact on the energy used to condition the building (Harvey 2009). Understanding how cognitive biases impact these decisions made by professionals during delivery could help supplement existing knowledge on how these biases impact occupants' decisions. This understanding is also a required step towards identifying effective methods to encourage building delivery stakeholders to make better energy decisions.

The aim of this paper is to engage researchers from the behavioral and social sciences to help address the decision making during building delivery that is preventing progress towards drastically improved energy performance in commercial buildings. In pursuit of this aim, the following objectives are accomplished:

- explanation and organization of energy decisions in commercial building delivery,

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[1] On average, computers account for 1.5% of this energy intensity and electronics another 5% (U.S. Department of Energy 2008), so increased use of these technologies does not fully explain the increase.

[2] The green buildings studied generally outperform comparable *new* buildings (Turner & Frankel 2008). However, taken as a whole, the existing building stock outperforms these green buildings. This is not a perfect comparison, as the green buildings studied represent a limited sample that is not necessarily a perfect cross-section of the entire commercial building sector. Still, the fact remains that much more needs to be done to reduce the energy intensity of US commercial buildings.

- hypothesis of cognitive biases which may influence these decisions, and
- development of a method to study these cognitive biases and apply this understanding to encourage better energy decisions in commercial building delivery.

The following "Background" section of this paper establishes the need to study cognitive biases on energy decisions for commercial buildings. The "Cognitive biases by project phase" section describes influential energy decisions and cognitive biases by phase of commercial building delivery. Then, the "Suggested research approach" section presents a method for studying the impact of these cognitive biases and using this improved knowledge to encourage better energy decisions. Finally, the "Conclusions" section discusses future research needs as well as implications of this paper.

Background

As a building project progresses through planning, design, construction and occupancy, the impact of decisions decreases, whereas the costs to make changes increase (Fig. 1) (Paulson 1976). Therefore, many important decisions, energy included, are made early in the project. Social science research shows that non-technical, non-economic factors can influence decisions. These factors have been examined for energy decisions, including those made by building occupants (Stern 1985). However, we must improve understanding of how these non-technical, non-economic factors influence crucial, early-phase energy decisions.

Decisions made during building planning, design, and construction

Key opportunities to cost-effectively impact a building's energy performance occur during the planning, design, and construction phases of building projects (Magent et al. 2009; Paulson 1976). In general, the sooner these decisions occur, the less likely they will negatively impact cost and schedule. For instance, elongating a building along the east–west axis is typically an effective design strategy to improve energy performance (Mazria 1979). This decision has minimal cost impact during the planning and design phase but would require drastic costs thereafter. Other essential energy performance decisions that occur early in the project include the following:

- Adoption of an integrated design approach, which emphasizes holistic design and differs from traditional practices that emphasize separate systems (e.g. site, structure, mechanical) (W. G. Reed & Gordon 2000);
- Participation in design "charrettes," in which a large group of project stakeholders collaborate to develop project solutions in the early stages of planning and design (Watson 1996); and
- Involvement of building occupants and operators in the planning, design, and construction process (Energy Star 2009).

For maximum impact, efforts to improve energy performance of buildings must consider the planning, design, and construction phases on building projects.

Rationality and the influence of cognitive biases on energy decisions

A "rational" decision is one that is in the best interest of the decision maker. This is referred to as optimizing utility, which in the narrowest sense is equivalent to maximizing profit for the decision maker. However, other factors such as pleasure and security are also important considerations for most decision makers seeking to optimize utility.

Improvements on the idea of rationality as simply optimizing utility consider that the rationality of individuals is bounded by information, time, and the cognitive limitations of their minds. For example, in this bounded rationality, rules of thumb might substitute for a full analysis, save time in the decision-making process, and even lead to better decisions than the theoretically optimal procedure (Gigerenzer 2006). Similarly, constraints such as time pressure, uncertainty, and changing conditions may mean that optimal high-stakes decisions are not the same as decisions in less pressing situations (Zsambok and Klein 2007).

Cognitive biases, which contribute to this bounded rationality, refer to our tendency to make errors in judgment-based habits or evolutionary necessity. A number of cognitive biases are described in the following section of this paper and in Table 2, and

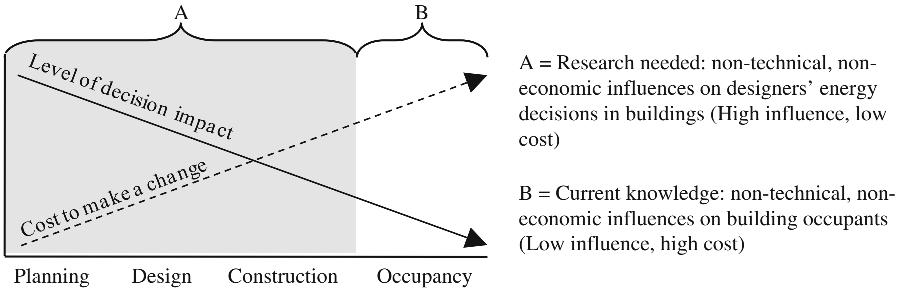

Fig. 1 The need to understand how non-technical, non-economic considerations effect early-phase energy decisions for buildings

more extensive descriptions are offered in popular books (Ariely 2008), textbooks (Wilkinson 2007), and compilations of papers (Camerer et al. 2003). Incorporating these biases has helped improve the theoretical foundation of fields including economics (Camerer et al. 2003), law (Sharp 1995), and medicine (Chapman & Elstein 2000).

Historically, research examining cognitive biases on energy decisions in buildings has focused on building occupants (Winett & Neale 1979; Shama 1983). A mid-1980s National Research Council report, "Energy Efficiency in Buildings—Behavioral Issues," discusses behavior and energy use in buildings for issues including adoption of energy retrofits and response to incentives for energy conservation (Stern 1985). Other studies from this period found that building occupants made energy decisions using analysis methods that were convenient but did not optimize outcomes (Kempton & Montgomery 1982); demanded unusually high energy cost payback before choosing energy-efficient appliances (Meier & Whittier 1983); and focused on easily observed factors, like turning off lights, regardless of the associated cost and energy savings (Yates & Aronson 1983). In the 1990s, researchers continued to incorporate behavioral science advances into studies of energy efficiency in buildings (Lutzenhiser 1993; Vine 1993). With rising energy costs and greater awareness of climate change, research examining the impact of cognitive biases on energy use in buildings is increasingly relevant in this first decade of the 21st century (Parnell & Larsen 2005; Wilson 2008; Wilson & Dowlatabadi 2007; Urge-Vorsatz et al. 2009).

The research that has examined non-technical, non-economic barriers to pre-occupancy energy decisions is focused primarily on the "business-as-usual" approach to design, which inhibits the integrated design process that could lead to improved energy performance that is cost-effective (Bordass et al. 2001; Vaidya et al. 2007). Another focus of this research has been the decisions of organizations that own buildings (DeCanio 1993; Koomey et al. 1996; DeCanio 1998). Barriers identified as preventing these owners from choosing the optimal level of energy efficiency include misalignment of various departments' goals and incentives; and difficulties transferring information across departmental boundaries (Kulakowski 1999). Early research in this area identified cognitive biases among stakeholders as one barrier to adoption of energy-efficient technologies in new commercial buildings (Koomey 1990).

Conclusions based on the literature

A common theme in research examining non-technical, non-economic influences, including cognitive biases, on energy decisions in buildings is the emphasis on the building occupants' decisions. This emphasis can be supplemented by including key decisions made during building delivery, which are also crucial when considering buildings' energy performance. The research described in this paper will extend the knowledge base through study of cognitive biases in energy decisions during planning, design, and construction of commercial buildings. Understanding these cognitive biases is the first step to mitigating them to promote better energy performance.

Potential cognitive biases by project phase

To identify cognitive biases with the largest impact on energy performance of commercial buildings, it is sensible to begin by examining the major energy decisions made during building delivery. For this paper, key energy decisions are identified through recommended approaches to incorporating energy performance in building delivery (Energy Star

2009). Cognitive biases hypothesized to impact these key energy decisions are discussed, organized by project phase, in the following sections.

These cognitive biases are represented in Fig. 2, which also shows the basic organization of the building delivery process, including the decision makers who typically lead and assist in the various phases (J. H. Reed et al. 2004). This delivery process can vary depending on contractual arrangements and other factors, such as the eventual use of the building. For instance, occupants will likely not be included in planning and design decision making when the project is being built by a developer to sell upon completion. These variations mean that specific findings may not be transferrable between projects that use different delivery process. However, the approach suggested in this paper is applicable across these variations in the delivery process.

The cognitive biases and energy decisions in this section are meant to illustrate the vast potential for research in this area. There are certainly more cognitive bias/energy decision combinations to study, some of which are listed in the appendix Table 2. A systematic approach to identifying additional cognitive bias/energy decision combinations is discussed in the "Suggested research approach" section.

Cognitive biases and energy decisions during planning

One of the first energy decisions during building delivery involves setting an energy performance goal. This decision, which guides the remainder of the project, is susceptible to the *anchoring* cognitive bias, which refers to the tendency for individuals to gravitate towards a predefined standard regardless of its relevance (Strack et al. 1988; Jacowitz and Kahneman, 1995). For example, people who are asked whether a country's population is more than or less than 5 million will anchor on that 5 million number. If these same people are subsequently asked the exact population of that country, they will answer closer to 5 million than a group that was never asked the first question. Building teams that anchor their energy goals on building codes, or even on green requirements like LEED,[3] could sacrifice more ambitious performance goals. Most building codes simply represent the maximum legal energy use of a building. The current LEED rating system, version 2.2NC provides full credit for reducing energy use 42% below code requirements. Although this reduction is an improvement over standard practice, exemplary buildings show that much greater energy savings are not only technically possible, they can be cost-effective.[4] Anchoring suggests that green building rating systems should consider using zero energy as a baseline, which would encourage building teams to anchor on this lower point instead.

The design charrette is another key aspect of the energy decision process in the planning phase. By combining representatives from numerous groups who are typically underutilized in the design process, breakthrough energy innovations are possible. For example, student participants can provide unique insight to design charrettes for an academic building on their campus. Perhaps students are most likely to use the building between 8 p.m. and 2 a.m., with greater occupancy leading up to final examinations. This accurate understanding of occupancy requirements is essential to optimizing energy performance. *Groupthink* could stifle these types of insights from charrette participants. Groupthink occurs when group members minimize conflict and reach consensus at the expense of fully evaluating ideas (Janis 1973). Groupthink explains why students are more prone to select a wrong answer if they know their classmates have also done so. Especially when suggestions come from new perspectives and participants, the groupthink bias could mean viable options and insights are overlooked, minimizing one of the primary benefits of holding the charrette in the first place.

Cognitive biases and energy decisions during design

An integrated design approach is critical to delivering buildings with drastically improved energy performance. This approach, in which designers work together and examine the building as a whole, is different from a common approach to design, in which the building is divided into systems and designers work in sequence. *Status quo bias* is an obstacle to implementing uncommon methods, such as the integrated approach.

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[3] LEED, which stands for Leadership in Energy and Environmental Design, is the green building certification system of the US Green Building Council.

[4] A recent study found that, for homes in the United Kingdom, greatly increased energy performance can actually be more cost-effective, per ton of carbon dioxide saved, than smaller improvements (Shorrock and Henderson, 2009).

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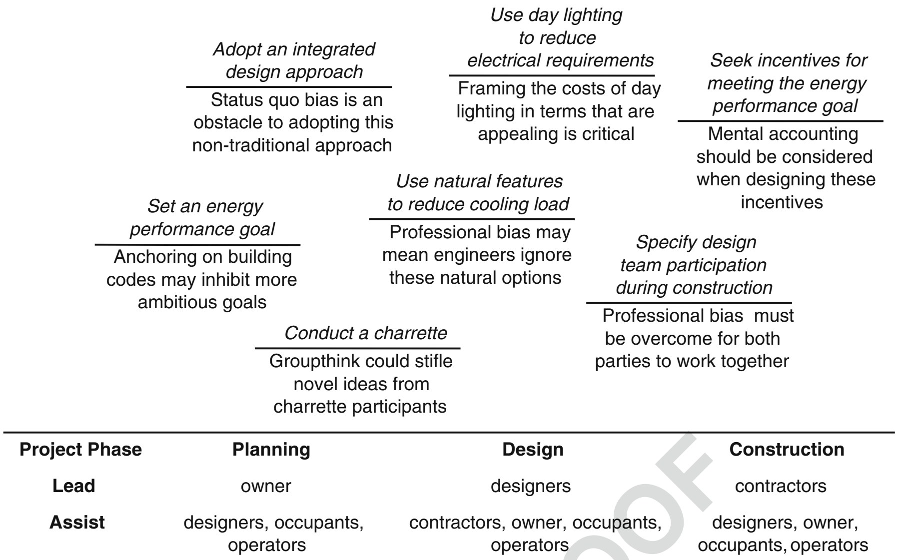

Fig. 2 Potential cognitive biases at key energy decisions by project phase [The stakeholders are listed as leading or assisting in the various project phases based on the conventions of contracting structures in the US building industry. Depending on contracting structures, these roles may change (e.g. contractors may play a more lead role in design).]

Status quo biases describe our reluctance to change from established behaviors in the absence of considerable incentives (Samuelson and Zeckhauser, 1988; Kahneman et al. 1991). The television viewer who watches the show immediately following their favorite show, rather than searching for something better on another channel, provides an example of this bias. Status quo bias may be a reason that, minus significant incentives to change, designers are reluctant to move towards a more integrated approach.

A key technical energy decision during the design phase is consideration of natural day lighting to reduce or eliminate the need for electric lighting. Day lighting strategies include larger windows and light shelves that reflect natural light deep into interior spaces. The *framing* of costs associated with day-lighting strategies might impact whether they appear reasonable or cost-prohibitive. Framing refers to how the presentation of a scenario or information impacts the decision to be made (Tversky and Kahneman, 1981). For instance, surgery with a 90% survival rate sounds more appealing than surgery with a 10% death rate, even though they are exactly the same. Returning to the light shelves example consider that light shelves cost roughly $100 per window. Many owners will not pay this premium based only on the potential future energy savings from reduced use of electrical lighting. Owners are more apt to pay for these same light shelves if their costs are framed to also include the reduced construction costs made possible because the light shelves have eliminated the need for other types of lighting.

A second technical energy consideration during design is the use of natural features to reduce cooling load. For instance, properly-located deciduous trees can shade windows during the summer, while allowing light and warmth in during the winter. However, *professional bias* might inhibit this energy decision. Professional bias can limit perspective by focusing excessively on the conventions of one profession. For instance, differing professional viewpoints in the healthcare field can restrict interventions to prevent injuries (Linder, 1987). Doctors, insurance agents, and lawyers each evaluate this injury prevention based on the conventions of their respective professions. When these different perspectives are not coordinated, the interventions are less effective. An example of professional bias in building delivery could occur when mechanical engineers are charged with meeting cooling needs in a building. These engineers may be biased to focus on cooling options that traditionally fall within their discipline, such as air-conditioning systems and controls. Natural features would likely be suggested by individuals from another profession, such as landscape architecture, and incorporation of these features requires avoiding professional bias.

Cognitive biases and energy decisions during construction

Professional bias may also influence key energy decisions during the construction phase if designers do not consider the perspectives of contractors and vice versa. Therefore, contracts that specify contractor participation during design and design team participation during construction may help ensure that energy-efficient design solutions are implemented. Avoiding professional bias would allow designers and contractors to work together more effectively.

Incentives for meeting energy performance goals might be considered during the construction phase. Federal, state, and local governments may offer incentives, such as tax credits, to the building owner. The owner could also offer incentives, such as financial bonuses for achieving energy goals, to members of the project team. *Mental accounting* should be considered when designing these incentives. Mental accounting is a specific type of framing in which the categorization of outcomes impacts the decisions made (Thaler, 1985). Mental accounting explains why gamblers will eagerly bet their recent winnings but hesitate to bet the same amount when it must be withdrawn from their bank account. Mental accounting could mean, for example, that a separate $100,000 bonus for achieving energy goals is a greater incentive to a design firm than the same amount added to a regular monthly payment.

Suggested research approach

The suggested research approach to study cognitive biases in energy during planning, design, and construction of commercial buildings is to (1) model and prioritize the critical energy decisions made during the delivery of building projects; (2) characterize the impact of cognitive biases on these decisions by adapting and applying established experiments from the behavioral and social sciences; and (3) devise and test decision-making contexts that address these cognitive biases and therefore support better energy efficiency decisions for buildings.

Model and prioritize critical energy decisions

A crucial step in this research is to model and prioritize the energy decisions made during building project delivery. Process models help represent, study, and improve processes (Curtis et al. 1992), and various modeling methods have been used to study building delivery (Tzortzopoulos et al. 2005; Austin et al. 1999; Klotz et al. 2007). A prioritized energy decision model would allow informed selection of cognitive biases for further study. Synthesizing existing resources would provide most of the content for this energy decisions model. For instance, energy decision points are presented in Energy Star recommendations for building design (Energy Star 2009) and in academic literature (Lapinski et al. 2006). To ensure energy decision points and cognitive biases with a large impact are the ones selected for further study, individual decisions within the energy decisions model could receive rankings for three variables: relative importance to energy performance (R); potential for cognitive biases (P); and suitability for choice architecture (S). These rough rankings would ensure, for example, that an energy decision point that is very influential to net-zero energy buildings (high R ranking) will not be chosen for detailed study if it has little potential for cognitive biases or suitability for choice architecture.

Characterize the impact of cognitive biases on high-impact energy decisions

Based on the R, P, and S rankings, decision points and cognitive biases can be selected for further study. From this information, hypotheses can be formed. Then, seminal studies from the behavioral sciences can be adapted and applied to test these hypotheses, characterizing the cognitive biases' impact on the selected energy decisions. The general process for these studies is described here using an illustrative example from a study of the impact of the anchoring bias on designers' selection of energy performance goals (Klotz et al. 2010). This same general process could be followed to test the high-impact hypotheses developed based on the R, P, and S rankings.

Step 1: Develop a hypothesis based on the selected decision point and cognitive bias

As discussed previously, the anchoring bias refers to people's tendency to gravitate towards a predefined standard (Strack et al. 1988; Jacowitz & Kahneman 1995). Anchoring could impact the key energy decision point where design teams select an energy performance goal for their building. Well-intentioned green building policies that suggest incremental energy improvements may act as anchors and cause designers to set less ambitious energy performance goals. Therefore, the hypothesis for this example study is that designers who focus on green building standards that reward incremental energy improvements will generally set less ambitious energy performance goals than designers who focus on more ambitious goals.

Step 2: Identify a seminal study of the cognitive bias to adapt and apply

The example study was guided by Jacowitz and Kahneman's (1995) method for studying anchoring effects. The method calls for a "calibration" group and an "anchored" group and compares estimates of each group for a set of uncertain quantities. This method is widely applied in subsequent studies of anchoring (Hurd 1999; Mussweiler & Strack 2000; Chapman & Johnson 1999).

Step 3: Adapt and apply the seminal study to the energy decision

To adapt Jacowitz and Kahneman's method and study anchoring on energy performance goals, professionals were randomly directed to one of three series of questions. One series set an anchor of 90%, one set a 30% anchor, and one set no anchor. All three series of questions ended with an identical question asking respondents to set an energy performance goal. The survey design tests whether the anchoring questions influence the energy performance goal that is set.

Step 4: Use the study results to characterize the impact of the cognitive bias

The results showed that respondents exposed to the 90% anchor set higher energy performance goals than respondents exposed to the 30% anchor. Even the respondents exposed to no anchor set higher goals than respondents exposed to the 30% anchor (Klotz et al. 2010). These results suggest that by considering the influence of anchoring, building rating systems could avoid inadvertently encouraging low energy performance goals.

Devise and test decision making contexts

Improved understanding of the impact of cognitive biases enables study of how to promote better energy decisions by organizing the context in which people make decisions or "choice architecture" (Thaler & Sunstein 2008). One example of effective choice architecture is when drivers license applicants are asked to check a box on a form if they *do not* want to be an organ donor. When this choice architecture is in place, the percentage of organ donors is much higher than when license applicants are asked to check a box if they *do* want to be a donor (Thaler & Sunstein 2008). As a strategy to address cognitive biases, choice architecture is generally less intrusive than regulation (Sunstein & Thaler 2003; Moxnes 2004) and can be implemented more rapidly than educational efforts (Oskamp 2000).

For the anchoring example, effective choice architecture might involve structuring green building rating systems so that incentives are available for energy reductions all the way to net-zero energy. Designers might then anchor on net-zero energy instead of the incremental improvements and therefore set more ambitious energy performance goals. Testing of choice architecture like this would follow the same general steps used to characterize cognitive biases. Because the cognitive bias and choice architecture strategies to address it are closely linked, researchers that characterize a cognitive bias are well positioned to test the corresponding choice architecture.

The application of choice architecture to energy decisions during building delivery remains underexplored. To illustrate this need, several choice architecture strategies are (priming, feedback, and disclosure) are discussed here along with an italicized question to show the potential relevance of the choice architecture strategy to building delivery (Table 1). Of course, specific choice architecture strategies would depend on the cognitive biases identified.

Feedback refers to the decision makers' ability to quickly see the impact of their decisions. For instance, informing users of their energy use as it happens is effective in reducing household energy consumption (Darby 2006). Perversely, informing households of how their energy use compares with their neighbors' results in the "boomerang effect," where households using more energy than average typically reduce consumption, whereas those using less than average are more likely to increase consumption (Schultz et al. 2007). *How does the rate of feedback on energy performance, perhaps through energy modeling programs, impact the design decisions made by various project stakeholders?*

Disclosure refers to others' ability to see the results of decisions. When decision makers know their

Table 1 Examples of choice architecture (CA) and potential relevance to this project

CA strategy	Description, example, and potential relevance
Priming (Herr 1986; Kay et al. 2004)	Description: People's previous experiences with a decision context impact their decisions. Example: Objects found in formal business environments, such as suits and briefcases, make people more competitive in group meetings. Relevance: Holding design meetings in a net-zero-energy building could lead to better energy decisions than holding the meeting in a standard building.
Feedback (Darby 2006)	Description: Decision makers' ability to quickly see the effect of their decisions. Example: Informing users of their energy use as it happens can reduce household energy use. Relevance: The rate of feedback on energy performance, perhaps through energy modeling programs, could impact design decisions.
Disclosure (Staats et al. 2004; Jin & Leslie 2003)	Description: Others' ability to see the results of decisions. Example: Requiring restaurants to display health scores can improve their future scores. Relevance: Design firms' energy decisions may improve if they were required to publicize their projects' energy performance.

choices will be publicized, they are more likely to act in the best interest of the public (Staats et al. 2004). This is one reason why requiring restaurants to display health scores can improve their future scores (Jin & Leslie 2003). *Would requiring architecture firms to report the energy performance of their previous work when soliciting new projects lead to more energy-conscious design firms?*

Priming refers to characteristics of a decision context that, based on decision makers' previous experiences with these characteristics, can impact the choices they make (Herr 1986). For example, objects characteristic of business environments, such as suits, briefcases, and boardrooms, make people more competitive in group meetings (Kay et al. 2004). *Could holding planning meetings in a net-zero-energy building lead to better energy decisions than holding the meeting in a building with standard energy performance?*

Conclusions

This paper has described the conceptual connection between cognitive biases, choice architecture, and energy decisions in commercial building delivery to encourage and guide much needed research in this area. Empirical studies can identify and characterize key cognitive biases on energy decisions in building delivery. This understanding can inform the development and testing of choice architecture that accounts for these cognitive biases and promotes better energy decisions. Then, the understanding of cognitive biases can be augmented through future research that adopts established decision models from related theories, including technology adoption, social and environmental psychology, and social construction. *Social construction* supplements the understanding of cognitive biases by considering the amount of energy use that is embedded in routine behavior (Shove 1998; Wilhite & Lutzenhiser 1999); *social and environmental psychology* complements the understanding of cognitive biases by helping explain the role of values, attitudes, and norms on designers' energy decisions (Borden 1977; Dennis 1990; Kempton et al. 1992; Schweizer-Ries 2008); and *technology adoption* emphasizes attitudes to examine the spread of new technologies (Rogers 1995; Jacobsson & Johnson 2000; Lund 2006; Dieperink et al. 2004; Vermeulen & Hovens 2006).

The aim of this paper was to engage researchers from the social and behavioral sciences to help address the decision making that is preventing progress towards improved energy performance in commercial buildings. In pursuit of this aim, the following objectives are accomplished through this paper:

- explanation and organization of energy decisions in commercial building delivery,
- hypothesis of cognitive biases which may influence these decisions, and
- development of a method to study these cognitive biases and apply this understanding to encourage better energy decisions in commercial building delivery.

The results of this and related future research could be valuable for building professionals (e.g. engineers, contractors, and architects) working on more energy-efficient buildings, owners managing a building delivery project team, and policy makers seeking to encourage more widespread adoption of energy-efficient buildings. This research could also inform the study of cognitive biases on energy decisions made by professionals in other industries. Because buildings represent a tangible and familiar way to illustrate concepts, the findings and methods from this project could be readily adapted by other industries.

This future research also may have implications for education in engineering, construction, and architecture. Simply recognizing cognitive biases could provide students in these disciplines with insight into their own decision-making process. For instance, a practicing engineer who learned about cognitive biases in their coursework might ask themselves: “Is the old design really the best option, or am I succumbing to cognitive bias?” Recognizing these cognitive biases is essential to avoiding their negative impacts. In addition, a more detailed understanding of these cognitive biases could supplement engineering equations and calculations, contributing to a more complete and accurate model of how decisions are made.

Appendices

Table 2 Example cognitive biases and their potential relevance to this project

Cognitive bias	Description, Example, and Potential Relevance to this Project
Status quo bias (Samuelson & Zeckhauser 1988; Kahneman et al. 1991)	Description: Established behaviors do not change without a significant incentive. Example: Watching the TV show immediately following a favorite show, rather than searching other channels for something better. Relevance: May contribute to reluctance to adopt new building technologies with improved energy performance.
Self-serving bias (Svenson 1981)	Description: People generally believe they perform better than average. Example: 88% of college students rate themselves as above 50% on driving skills. Relevance: May lead to complacency among designers who perceive their projects as having above average energy performance.
Framing (Tversky & Kahneman 1981)	Description: The presentation of a scenario impacts the decision made. Example: Surgery is more appealing if its success rate is described as “90% of patients survive” rather than “10% of patients die.” Relevance: Explaining energy technologies in terms of annual savings if adopted may be less effective than explaining these same technologies in terms of costs if not adopted.
Mental accounting (Thaler 1985)	Description: The categorization and coding of outcomes impacts the decisions made.

Table 2 (continued)

Cognitive bias	Description, Example, and Potential Relevance to this Project
	Example: Gamblers are more likely to bet $200 of previous winnings than $200 withdrawn from their savings account. Relevance: Annual energy savings can be overlooked if they are part of a separate budget from the initial building costs.
Professional bias (Linder 1987)	Description: Perspective can be limited by focusing on the conventions of one profession. Example: Professional views of healthcare (e.g. medical, legal, economic) have differing causal frameworks, which combine to constrain interventions. Relevance: The differing professional views of architects, engineers, and contractors may inhibit the integrated design process essential to net-zero-energy building design.
Loss aversion (Kahneman et al. 1991)	Description: Avoiding losses is preferred to acquiring gains. Example: People are twice as disappointed to lose $100 as they are happy when they gain the exact same amount. Relevance: Contributes to reluctance to adopt unproven building technologies with greater energy efficiency.
Anchoring and adjustment (Strack et al. 1988; Jacowitz and Kahneman, 1995)	Description: Gravitation towards a predefined standard, regardless of its relevance. Example: People asked first whether a state has a population more or less than 5 million are likely to guess around 5 million if they are subsequently asked the actual population. Relevance: Seeking to minimize energy using building codes (or LEED requirements) as a baseline may be less effective than using zero energy as a baseline.
Hyperbolic discounting (Green et al. 1994)	Description: Smaller, immediate rewards are selected over larger, delayed ones. Example: Offered $50 now or $100 in 1 year, many people choose the former. However, given the choice between $50 in 5 years or $100 in 6, almost everyone will choose the latter. Relevance: The delayed reward of energy savings can be less appealing than the instant gratification of the lowest first-cost.
Groupthink (Janis 1973)	Description: Group members minimize conflict and reach consensus without fully evaluating ideas. Example: Students are more prone to select a wrong answer if they know their classmates have also done so. Relevance: When they are proposed by a single member of the design team, Innovative energy saving ideas may be ignored in favor of common practice.

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