THE STATE OF SUSTAINABILITY BEST PRACTICES IN CONSTRUCTION: A BENCHMARK STUDY

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ABSTRACT

During the last decade, sustainability-related technologies and practices have become increasingly common among construction companies, both in the home office and on the job site. Multiple drivers are fueling this trend, including government policies for sustainability in capital projects and increased recognition of the benefits of sustainable practices in the private sector. However, the extent to which sustainability-related technologies and practices have been adopted by companies in the field has not been systematically documented. This study used semi-structured interviews and field observations to document the sustainability-related practices of 28 construction firms in the eastern United States. The purpose of the study was to benchmark current industry use of construction sustainability best practices. Findings of the study show that most firms have tried sustainability practices in the field on at least some of their projects, sometimes without being aware that those practices were related to sustainability. Considerable variation was observed among self-reported trial and adoption rates across the practices in the inventory. This study serves as a first step toward understanding why some sustainability innovations are being embraced more readily than others, and may lead to a better understanding of how to increase adoption of sustainability innovations.

KEYWORDS

sustainability, construction, best practices, benchmark

INTRODUCTION

Sustainable practices and technologies have entered the forefront of the construction industry. Since 2000, membership in the U.S. Green Building Council (USGBC) has grown from 41 members to over 18,800 members in 2009 and has continued to rise (Ahn and Pearce 2007; 2009). Additionally, as the number of USGBC members increases, more public and private corporations are moving toward LEED certified buildings as part of their objectives for new building projects. Many federal, state, and local governments and related organizations, including the U.S. Army Corps of Engineers (USACE) and the U.S. General Services Administration (GSA), have implemented mandatory green building standards (ibid.; Keysar & Pearce 2007; Pearce et al. 2007; DuBose et al. 2007). In the private sector, IBM, Toyota and Ford Motor Company are among the growing population of companies becoming more engaged in LEED design and green building practices (Ahn & Pearce 2007).

As owners begin to include sustainability goals as part of their objectives for capital projects, project delivery organizations, including architectural, engineering, and construction organizations, will adapt to meet the needs of this market by employing a variety of sustainability-related technologies and practices as part of capital project delivery. These technologies and practices range widely across all aspects of capital project delivery and corporate operations, but all have benefits in terms of reduced impact to the natural environment, increased efficiency of resource use, and/or enhancement of social, health, or economic benefits to facility users.

A need exists to better understand what types of sustainability-related innovations are most easily and effectively adopted over time by project teams in capital projects. This knowledge not only sup-

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ports the selection of successful tactics for use in future projects, but also provides key information to rethink tactics that are not being widely diffused. Establishing a benchmark of the current status of sustainability-related construction innovations can prove helpful in not only understanding which companies are using what practices and technologies, but also why they are choosing to use them and how to design future practices and technologies to be more successful. This study represents an initial benchmark of current practice against which future capital project activities can be compared.

METHODOLOGY

To establish a benchmark of the use of sustainability-related practices by construction firms, this field-based study employed a combination of semi-structured interviews, direct observation, and in some cases, participant observation of field practices. Data were collected by 43 undergraduate interns participating in an internship-for-credit experience during Summer 2007 through Virginia Tech's Department of Building Construction and the Myers-Lawson School of Construction (Pearce & Fiori 2009; Fiori & Pearce 2009; Pearce et al. 2010). Methodological validation was established by multiple students collecting data independently while employed by the same companies. Data were also spot-checked by supervising faculty throughout the summer internship period. Interns uploaded their findings into an online survey system that was then used to compile and analyze the data. Analysis was undertaken using descriptive statistics.

Data Collection Methods and Protocol

Interns were provided with detailed protocols for collecting data about sustainability-related best practices, and were briefed on strategies for triangulating data using multiple methods to answer the questions on the protocols. The protocol for sustainability best practices* was one of five designed as part of the *Synergistic Learning and Inquiry through Characterizing the Environment for Sustainability* (SLICES) program at Virginia Tech, which involves students engaged in summer internships in collecting benchmark data about industry practices.

The sustainability best practices protocol included two major focus areas: corporate-level practices applicable as part of the firm's general operations, and project-level practices applied in one or more specific capital projects with which the firm is involved. 37 corporate-level practices such as office waste recycling and green travel policies were included in the first part of the protocol. This list of practices was assembled from a variety of sources in the sustainable business practices literature and sustainable construction literature (Bennett & James 1998; Blackburn 2007; Carson & Moulden 1991; Charter & Polonsky 1999; Hoffman 2000; Holliday et al. 2002; Nattrass & Altomare 1999; Ottman 1998; Romm 1994; Russel 1998). Interns were required to identify whether or not their companies currently used each of these practices through a combination of direct observation, review of documentation such as corporate sustainability reports, and interviews of corporate personnel.

The second part of the protocol listed 115 project-level practices that could be implemented on individual construction projects. To improve the usability of the list during data collection, the list of practices was grouped into 11 clusters as follows, with the number of practices included in each cluster indicated in parentheses. Groupings were developed by the research team and served as an index for the long list of practices to make it easier to find particular items and ask related questions at the same time.

- Project Implementation Plans (7)
- Sustainable Procurement Practices (12)
- Sustainable Contracting Practices (7)
- Temporary Construction Materials (15)
- Sustainable Site Management Practices (13)
- Sustainable Project Management Practices (12)
- Sustainability Audits, Benchmarking, and Metrics (5)
- Indoor Environmental Quality Management (20)
- Solid Waste Management (12)
- Energy Best Practices (8)
- Alternative Transportation/Equipment (4)

Interns were asked to determine the current status of each practice for their company across all the projects with which their company was previously

*The full set of protocols used for collecting benchmark data is available online as part of the Engineering Pathway Digital Library (http://www.engineeringpathway.com). Search this site for "Sustainable Construction Benchmarking" to locate relevant protocols.

or currently involved. Practices ranged from use of bio-based form oils and dust suppressants, to on-site waste separation or coverage of sustainability in toolbox meetings, to use of occupant education plans and were derived from a variety of sources in the sustainable construction literature (Pulaski 2004; PTI 1996; Wilson 2001; USGBC 2007). Based on interviews, direct observation, and participant observation, interns established a value for each practice on the following scale:

1 – Never tried the practice/Not applicable

2 – Tried the practice on one or more projects in the past, but discontinued or abandoned it

3 – Presently use the practice on some of our projects

4 – Presently use the practice on all of our projects

5 – Don't know

Explanations of each practice and links to web sites with more information were provided to clarify what each practice entailed. Interns also had access to an internet-based discussion board to contact both their peers and supervising faculty with questions as the data collection progressed.

Sample Population

An earlier protocol in the five-protocol series established basic demographic data about the companies included in the benchmark study. A total of 35 firms constituted the study sample, although only 28 firms participated in the sustainability best practices protocol. The population characteristics shown in the following figures represent the whole sample of 35 firms.

Figures 1 and 2 show the type of work performed by the sample population in terms of project sector and project delivery method. The sample represented here contained disproportionately more commercial construction firms than the industry at large, and contained no firms whose primary sector of work was industrial construction. In terms of project delivery method, the distribution across delivery methods was more evenly split.

Figure 3 shows the approach of companies in the sample to performing work. The majority of firms surveyed extensively use subcontracting as a means of accomplishing work requirements. A comparatively small share of the population mostly

FIGURE 1. Type of work by sector.

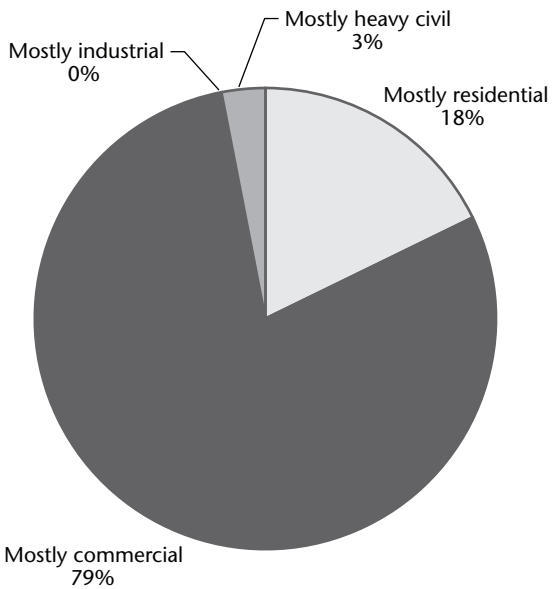
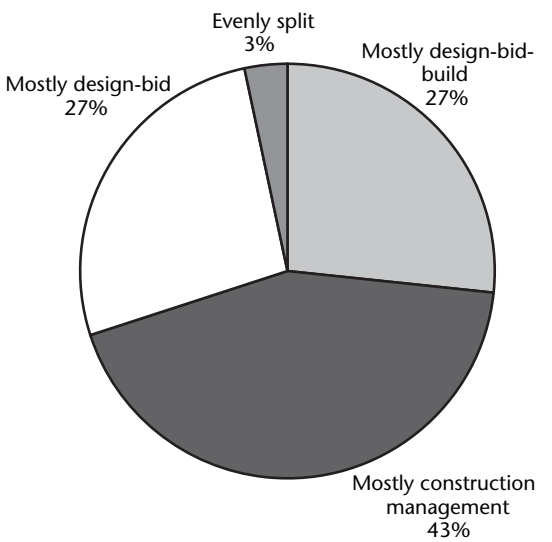
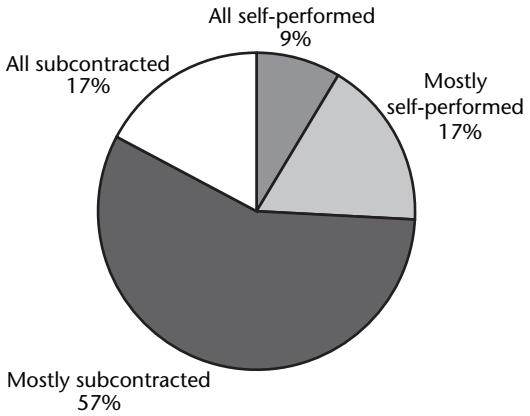


FIGURE 2. Type of work by delivery method.



or completely self-performs their work. Among the companies in the sample were several specialty subcontractors who comprised these firms. Figure 4 shows the degree to which firms use union vs. non-union labor to accomplish their work. In terms of union affiliation of their workforce, most firms in the sample reported that they use mostly or all non-

FIGURE 3. Work performance approach.



union labor on their projects. The states in which interns were employed by these firms included New York, Connecticut, New Jersey, Pennsylvania, Michigan, Maryland, the District of Columbia, Virginia, North Carolina, Tennessee, Georgia, and Florida.

Figures 5 and 6 show the primary type of client each firm serves and the average size of project by order of magnitude. The majority of firms in the sample primarily do projects for private sector clients. The average project size in terms of order of magnitude is primarily in the $10 million to $100 million range, meaning that firms in the sample are fairly large. While the average size of firm in terms of full time employees was 1013.5, the standard deviation of firm size was 2116, indicating the extremely broad range of company sizes. The largest firm in the sample had over 7,000 full time employees, while the smallest had only nine. The average annual project volume was $832 million per firm, with the smallest reported volume of $2.6 million and the largest annual volume of $10 billion for the largest firm in the sample. Finally, Figure 7 shows the age of companies in the sample. The youngest company in the sample was only five years old, while the oldest company was 123 years old.

Overall, the population sample included a broad range of companies, even though it was relatively heavily weighted towards larger general contractor firms who do private sector commercial work. This sample bias is likely due to the nature of firms who can afford to hire summer interns and who recruit those interns from academic programs focusing primarily on building construction.

FINDINGS

The results of the data analysis are divided into two groups. The next 11 subsections describe results of the inventory of sustainability best practices applied at the level of the individual project, i.e., project-level practices, for each of the 11 clusters described in the methodology. Each item is normalized as a percent-

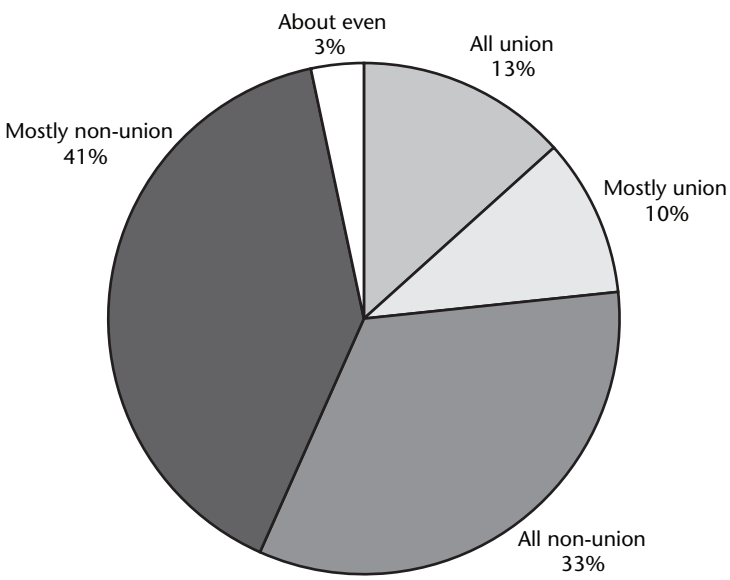


FIGURE 4. Union affiliation of workforce.

FIGURE 5. Primary type of client.

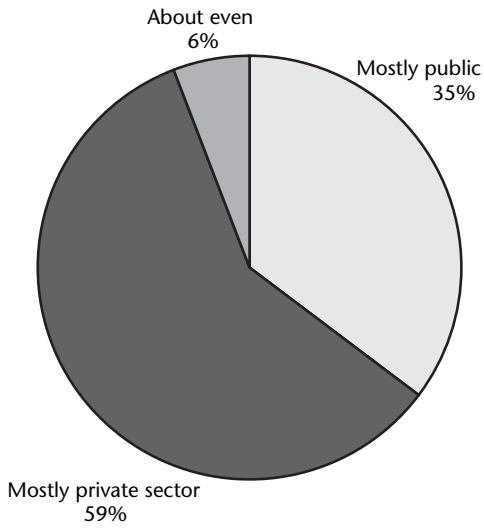
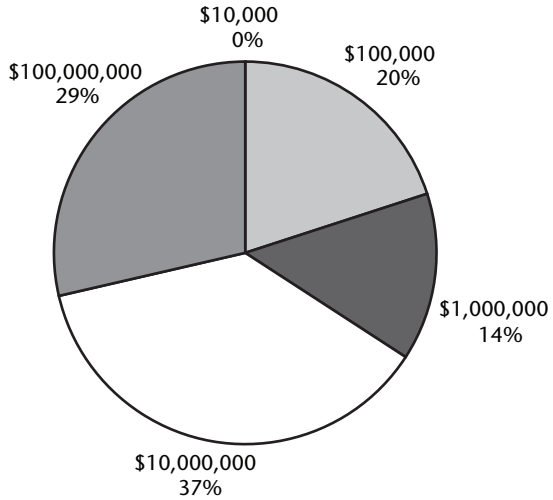


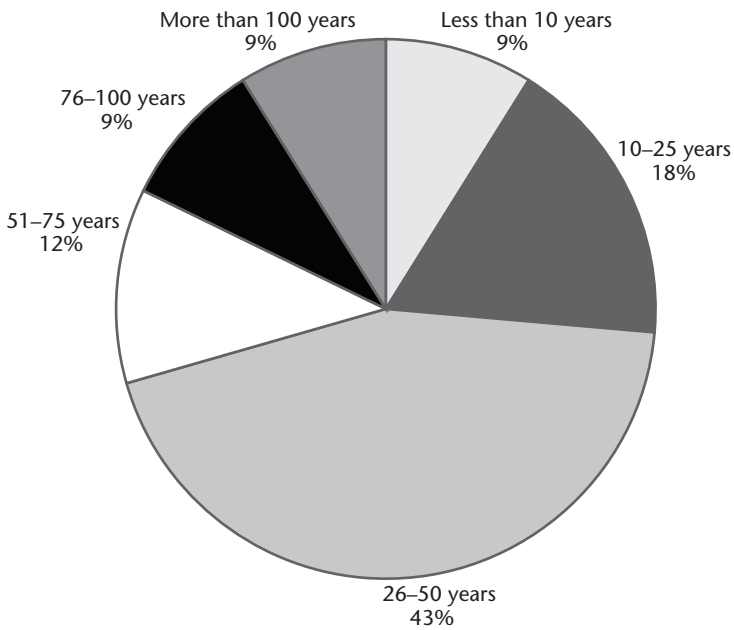
FIGURE 6. Average size of project (order of magnitude).



age of total responses. Responses are on a five-point scale, with four indicating "used on all projects" and one indicating "never used." Items are grouped into the same clusters as on the original survey to facilitate comparison of related or similar practices.

The final subsection describes the level of adoption of the 37 corporate-level sustainability practices associated with general corporate operations. These items are tabulated based on yes or no answers that represent a "snapshot in time" of what practices were presently in use during the study period. The final subsection shows the items from least to most frequently adopted and discusses the findings resulting from this part of the protocol.

FIGURE 7. Company age.



Sustainability-Related Project Implementation Plans

The first group of practices involves the existence and/or use of sustainability-related project implementation plans, including standard plans targeting goals such as reducing environmental impacts of construction or creating healthy conditions for workers, occupants, or tenants. Of the companies surveyed, a vast majority employed formal safety plans on all projects (Figure 8). This is most likely driven by concerns for legal liability and federal Occupational Safety and Health Act (OSHA) regulations. Along those lines, it generally appears that adoption of different implementation plans are being driven by regulation. For instance, erosion and sediment control (ESC) plans and spill/hazardous waste management plans are being required for an increasing number of projects under federal or local codes and regulations. Other plans such as indoor air quality management and site disturbance plans are largely optional, even for projects pursuing formal certification under the Leadership in Energy & Environmental Design (LEED) rating system. The two plans most likely to be required by law (safety plans and erosion/sedimentation control plans) were the most frequently adopted, while the least frequently adopted plans, at least across *all* projects, were optional, e.g., indoor air quality management plans and site disturbance/habitat protection plans.

Sustainable Procurement Practices

Figure 9 shows the reported frequency of use of sustainable procurement practices. The first eight practices in this category deal with the use of products with specific attributes such as recycled content or certification by third-party organizations such as Green Seal. Use of these products on a project is often controlled by design, as is reflected by the large reported values of "Use on some projects". The remaining practices require more detailed interaction with vendors. There appears to be a split for some of these projects that reflects more general corporate policies. For instance, the practice with the greatest percentage of "Use on all projects" is the use of supplier takeback clauses. These may be part of existing contractual arrangements with vendors common across all of a company's projects.

Sustainable Contracting Practices

Sustainable contracting practices (Figure 10) are some of the least used practices evaluated in the survey. These practices focus on sustainability-related selection criteria, contractual provisions, or incentives related to project team selection for construction projects. At least 30% of companies had never tried to use any of the mentioned sustainable contracting practices on their projects, and at least 80% of companies had either never tried the practices or only used them on some projects. The sustain-

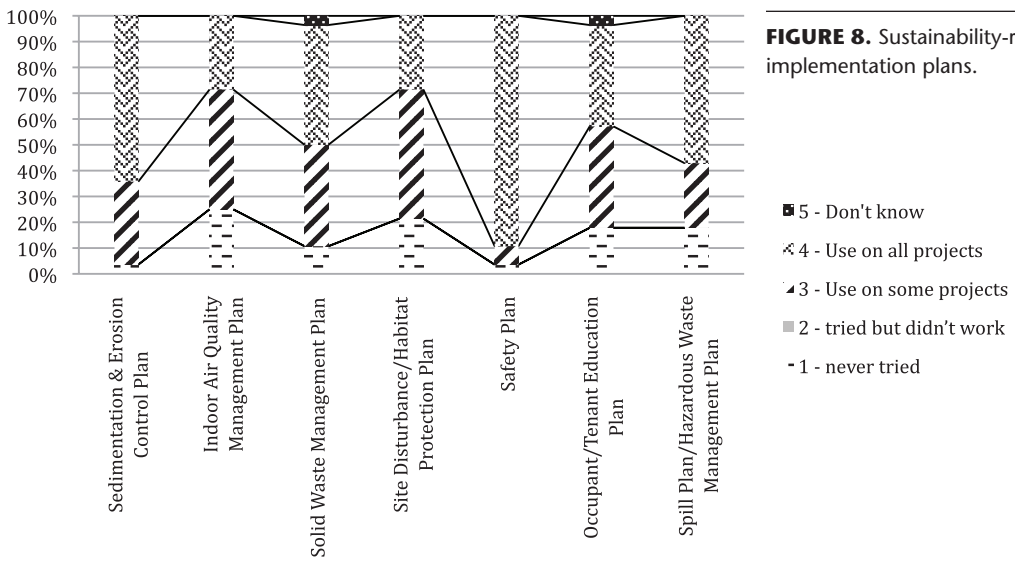


FIGURE 8. Sustainability-related project implementation plans.

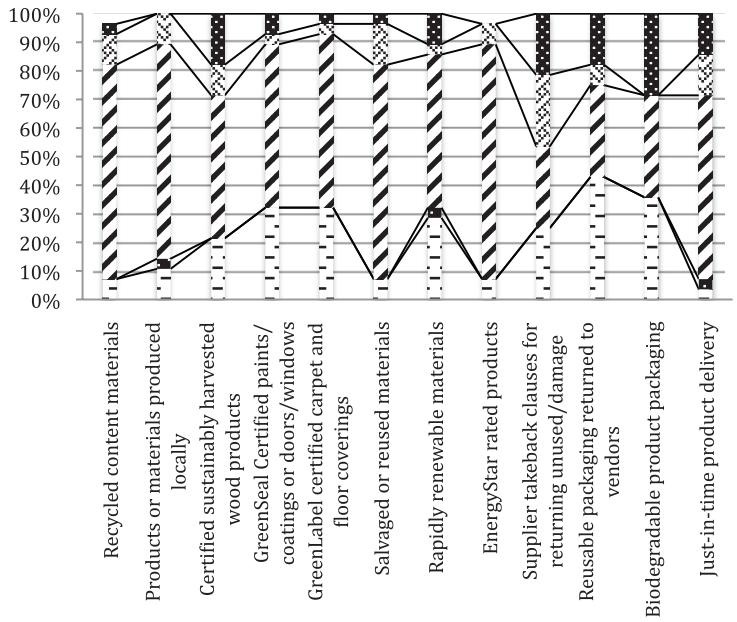


FIGURE 9. Sustainable procurement practices.

able procurement practice used most frequently on all projects was the use of incentives or penalties as part of contracts for meeting sustainable procurement goals. These types of contractual provisions provide a clear means for articulating expectations and responsibilities for achieving project sustainability goals.

Temporary Construction Materials

Best practices related to temporary construction materials (Figure 11) deal primarily with bio-based, reused, or recycled temporary materials and equipment. The most frequently used best practices in this group were reusable formwork, shoring, and bracing; reuse of excavation spoils and topsoil; and reuse

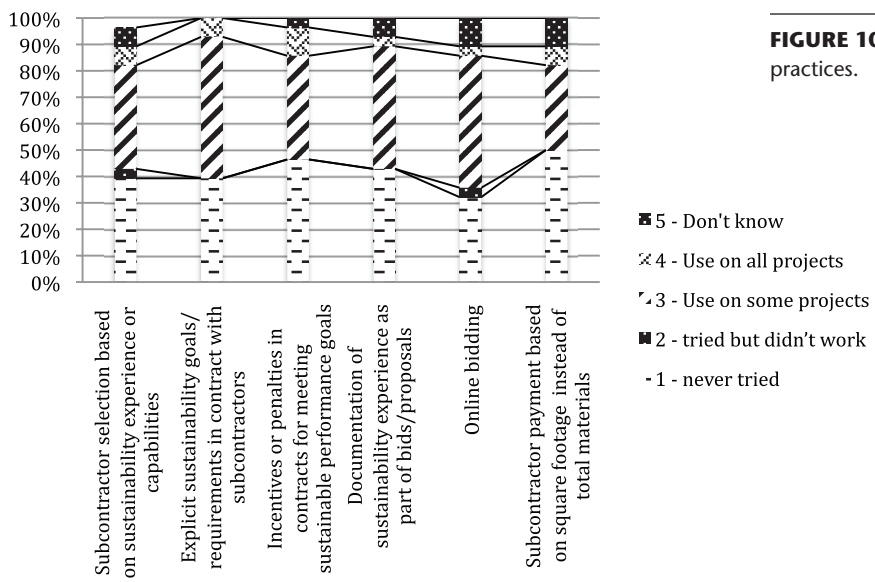


FIGURE 10. Sustainable contracting practices.

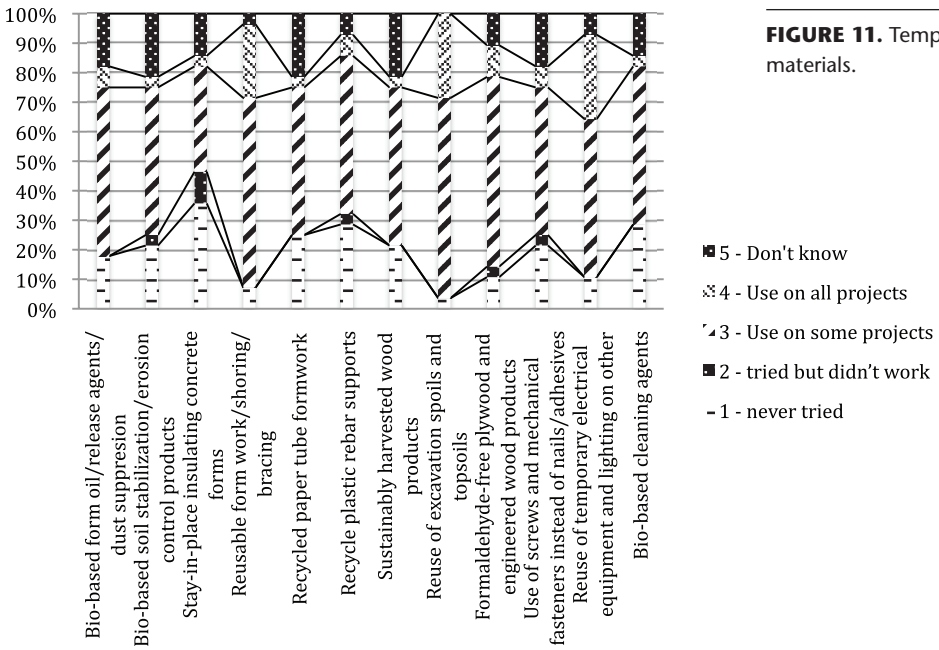


FIGURE 11. Temporary construction materials.

of temporary electrical equipment and lighting on other projects. These are also examples of practices that have been industry standard for a long time due to their cost saving potential and practicality. Although they each have distinct sustainability benefits due to conservation of resources and reduction of waste from a project, they may not be thought of as specifically sustainability-related by construction companies. The products reported as never tried by the highest number of firms were both related to concrete: stay-in-place concrete forms and recycled plastic rebar supports. Both of these technologies may not be as frequently used in larger commercial or industrial construction projects and may be more familiar to concrete subcontractors than to general contractors. Thus, this pattern may be more reflective of the distribution of companies in the sample than of industry practice in general.

Sustainable Site Management Practices

Sustainable site management practices (Figure 12) focus on activities aimed at reducing or repairing environmental damage to the site or neighboring sites during construction. These practices are generally well used with the exception of site natural resource inventories/conservation programs, capture and reuse of on-site water for dust control, and selling or donating salvageable plants. Most common in this category is use of stormwater best management practices. As with management plans, this is likely driven by regulatory requirements, since federal regulations require stormwater management on all projects greater than one acre in size (EPA 2008). Firms may also have recognized the financial benefits of front-end planning of site disturbance, including measures for tree and vegetation protection, planning for site circulation, limiting disturbance to areas that will be paved, and minimized disturbances to slopes.

Sustainable Project Management Practices

Sustainable project management practices include a wide variety of tactics typically employed by project managers as part of or in support of project implementation, including addressing sustainability issues at meetings, electronic document management, and sustainability and constructability reviews. As shown in Figure 10, these practices are widely used to some degree with the exception of assigning a sustainability champion to the project and bar coding/RFID tags for project inventory. As with other measures, use of RFID tags may not be associated with sustainability in the mind of many project managers, but its role in optimizing material

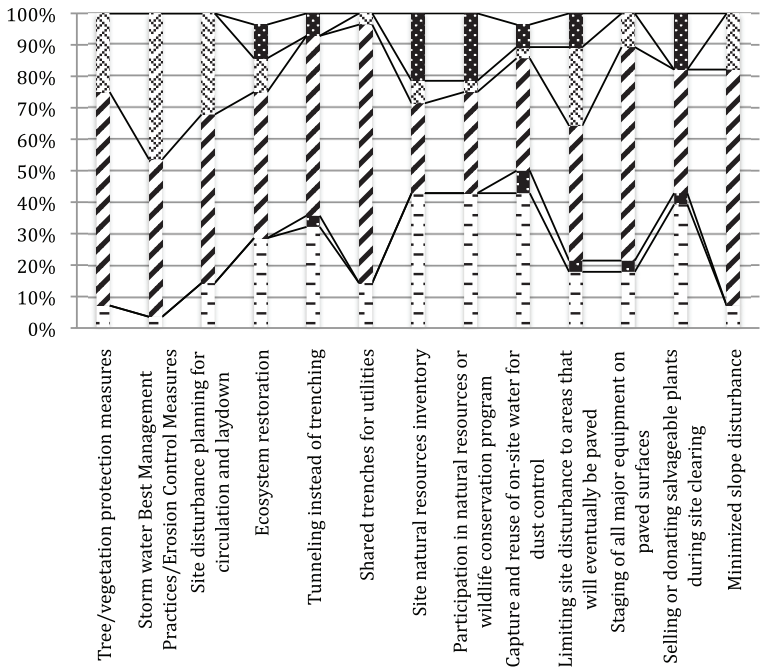


FIGURE 12. Sustainable site management practices.

use and reducing waste has sustainability benefits. Commonly used measures include constructability analysis and electronic document submittal.

Sustainability Audits, Benchmarking, and Metrics

Sustainability-related audits, benchmarks, and metrics (Figure 14) involve using formal rating systems and processes to evaluate the performance of a facility in terms of key sustainability variables. These tactics seem to be used widely on at least some if not all projects for responding companies. For example, over 60% of companies had used the Leadership in Energy & Environmental Design (LEED) green building rating system on at least some of their projects. Energy auditing, measurement and verification,

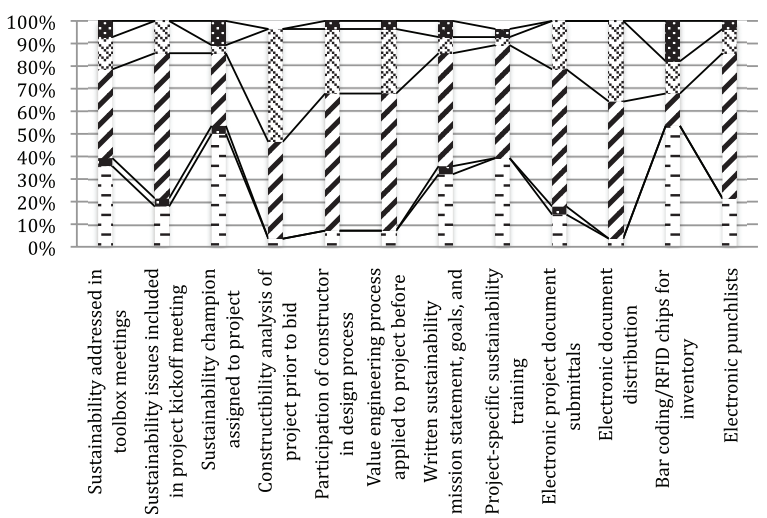


FIGURE 13. Sustainable project management practices.

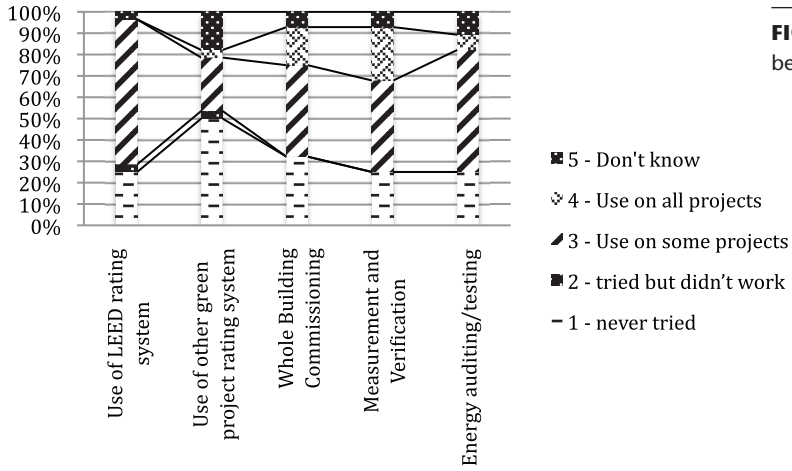


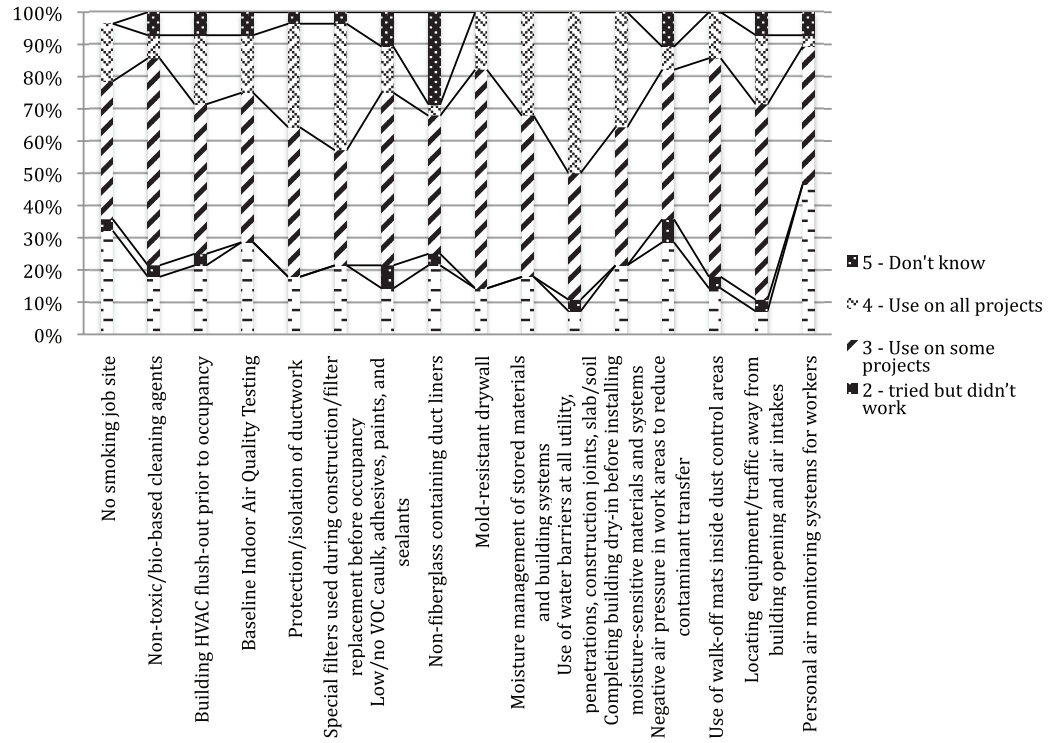
FIGURE 14. Sustainability audits, benchmarking, and metrics.

and whole building commissioning were also used by over half of participating companies for some or all of their projects. The use of green building rating systems other than LEED was also reported for at least some projects by approximately 30% of companies, although it was not nearly as prevalent as the use of LEED.

Indoor Environmental Quality Management

Practices under Indoor Environmental Quality (IEQ) Management target actions associated with preventing or mitigating future problems faced by building occupants after the project is complete. These practices had considerable variation in use among surveyed companies (Figure 15). Most fre-

FIGURE 15. Indoor environmental quality management best practices.



quently used practices included use of water barriers at all points of potential entry to the building, moisture management of stored materials, and use of mold-resistant drywall. These practices all reduce the risk of moisture problems and subsequent mold growth in buildings. Their common use may be due to contractor awareness of liability issues associated with mold. The least commonly used practices were non-fiberglass-containing duct liners and personal air monitoring systems for workers. Responses related to duct liners may be due in part to the fact that not all responding companies are involved with construction of duct systems as part of their work.

Solid Waste Management

Solid waste management best practices (Figure 16) include a range of material management and waste diversion practices that both increase the efficiency of resource use and reduce the waste stream from construction projects. These practices exhibited broad adoption on at least some projects by a majority of contractors. Construction waste recycling, material storage to prevent on-site damage, and prefabrication of materials were used on at least some if not all projects by over 90% of responding companies. Companies were less familiar with strategies such as donation of unused materials to charity and centralized cutting stations as ways to manage solid waste more sustainably on the project site.

Energy Best Practices

Energy-related best practices (Figure 17) had some of the highest use results of the entire survey. Shutting off temporary lighting and reduced elbows/bends in piping and ductwork were used on at least some projects by 90% or more of responding companies. Within this category, the use of photovoltaic power supplies for construction and warning signage had the least reported use with about 30% use on at least some projects. The practice of energy efficient framing techniques had a notable level of uncertainty in responses. This uncertainty may be due to the way in which the practice was phrased. It could also be due to the relatively low proportion of residential construction companies, which is where the majority of predominantly wood-based energy efficient framing techniques are used.

Alternative Transportation/Equipment

Alternative transportation and equipment practices are illustrated in Figure 18 and include alternative fuels, incentives for alternative types of transportation, and increased efficiency of vehicle use. The data shows considerable variation for these four practices. Over 60% of companies, for instance, had never tried alternative fuel vehicles as of the time of the survey. The other three practices—centralized refueling, reduced equipment idling, and encouraging alternative transportation to work—all had greater levels of

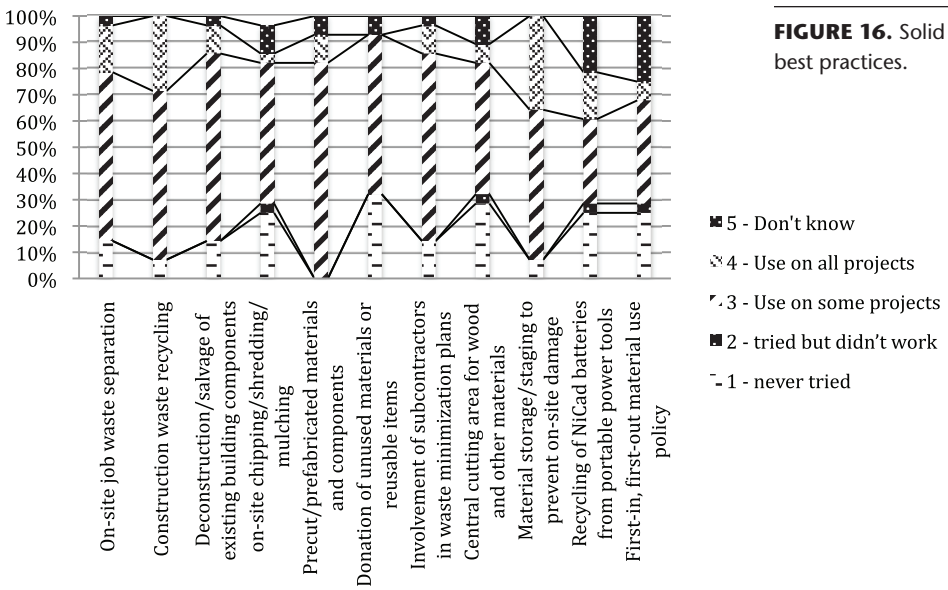


FIGURE 16. Solid waste management best practices.

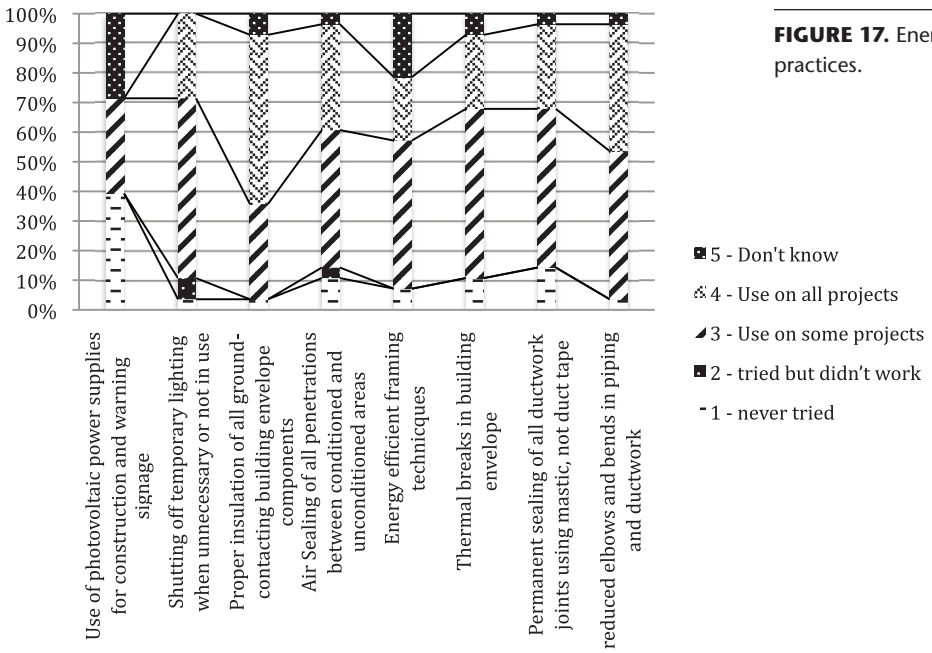


FIGURE 17. Energy-related best practices.

uptake, at least on some projects. These three practices require low or no capital expense to implement, while the capital costs of alternative fuel vehicles could be considerable for many companies.

Corporate Sustainability Best Practices

The second part of the survey was designed to determine which sustainability practices were present at the corporate level, i.e., were applicable company wide and not just on individual projects. Responses to this question were yes/no. Figure 19 shows the survey responses for corporate best practices in order from least frequently used to most frequently used. The most common practice was a recycling program for office waste, undertaken by nearly 80% of the companies surveyed. At the other end of the spec-

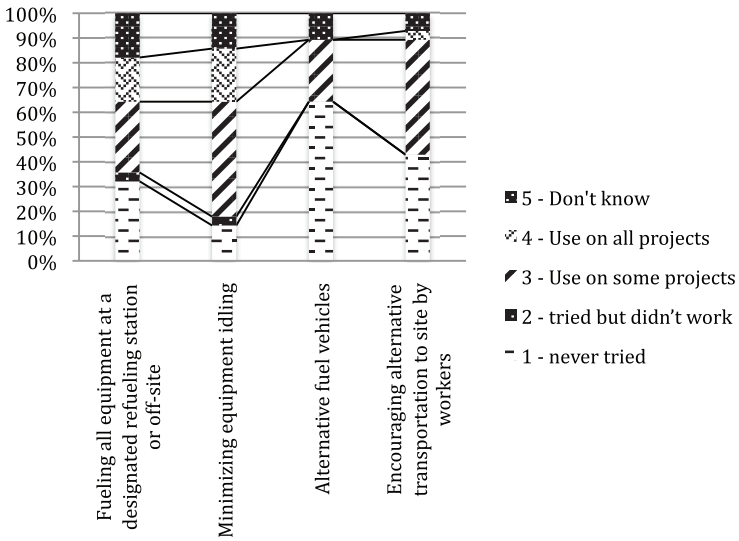
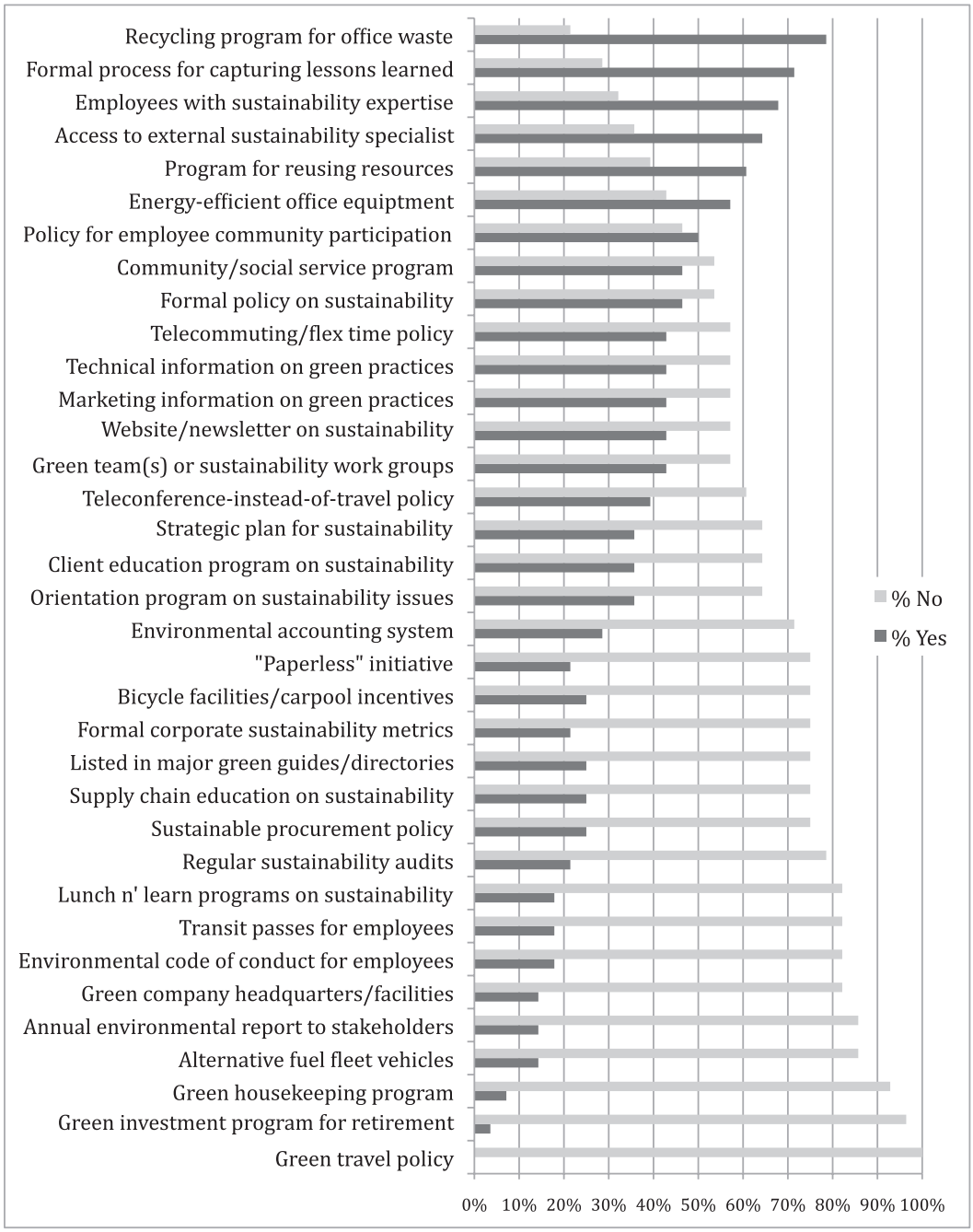


FIGURE 18. Alternative transportation/ equipment practices.

FIGURE 19. Corporate sustainability best practices.



trum, none of the companies had a green travel policy, and fewer than 10% of companies had a green housekeeping program at their own offices or a green investment program for retirement plans.

DISCUSSION AND CONCLUSIONS

The findings of this benchmark study provide a perspective on what practices are being adopted company-wide vs. on a project-by-project basis. Generally, the industry seems to be experimenting with sustainable practices on some, if not all, capital projects. This is reflective of the increased awareness of the need for sustainability and increased willingness of owners to request or require sustainability practices.

The initial benchmark will provide a point of reference for subsequent data collection and analysis to evaluate trends over time. These trends will serve as the basis for conclusions about industry preferences and experiences with specific practices that cannot be drawn from a sample representing a single point in time. They can also be compared against changes in regulation and policy that influence owner requirements for new practices. There is still a long way to go, but industry is at least aware of the need for sustainability and appears to be actively trying to achieve it. The data in this study support a perception that the industry is embracing new technologies and adapting to a changing focus in the economy and construction industry. However, the data also suggest that there are a wide variety of practices and technologies that are not being used extensively. The reasons behind these different adoption rates are unclear without future data points against which to compare the current findings.

Additional research is needed to determine why some sustainability practices are more diffused than others throughout the industry. An extensive body of knowledge exists to explain diffusion of innovations as a function of innovations, the people or organizations that adopt them, and the context in which adoption occurs. While outside the scope of the present study, this direction of study is rich for further investigation. A better understanding of the factors affecting adoption is needed to formulate strategies to encourage adoption of sustainability best practices across a wider population of organizations and projects. As a first step toward that understanding, this study provides an initial benchmark of the state of the industry as a point of reference for future work.

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