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1.0 Executive Summary

The goal of this survey was to understand the use of green building analysis tools among U.S. architects. Green building analysis tools are broadly defined, including software for energy modeling, daylight modeling, and lifecycle assessment of building materials; multi-functional tools; and other types of quantitative analysis related to the design of green buildings. The survey also considered contextual factors related to the use of green building analysis software. Specifically, the survey aimed to understand (1) frequency of green building and green building practices generally, (2) most-used early-stage 3-D modeling and BIM tools, (3) most-used green building analysis tools, and (4) strengths and weaknesses of existing green building analysis tools.

The survey collected responses from both architecture professionals and current students. Survey data was collected in October 2011; a total of hundred seven (107) valid responses were collected, nearly equally split between professionals and students. For a discussion of survey methodology, see Appendix B.

1.1 Early-Stage Modeling Software

The 3-D modeling and BIM platforms most frequently used in conceptual or schematic design appear to be, in order: (1) Google SketchUp, (2) Autodesk AutoCAD, (3) Autodesk Revit, and (4) Rhino. Large firms (50+ employees) overwhelmingly prefer Revit, while small firms eschew it; and small firms (1 to 49 employees) use AutoCAD most frequently. Current students use AutoCAD less frequently than professionals, and SketchUp more frequently. Overall, SketchUp is not only the most favored software, but is the most likely to be used with some regularity by virtually all demographics.

1.2 Green Building Practices

Self-reported familiarity with green building practices was high among both students and professionals; and firms of all sizes reported frequently engaging in green building (large firms more often than small). Use of green building analysis tools, however, is extremely infrequent, with an average score of 1.21 on a scale of 1 to 5. This low level of use
is consistent across all demographics. There is clearly a good deal of room for growth in the area of green building analysis software.

1.3 Use of Green Building Analysis Software

The most-used green building analysis tool is, by a large margin, Autodesk Ecotect. Runners-up differ by demographic, and included Autodesk Vasari, Autodesk Green Building Studio, EnergyPlus OpenStudio, and, by certain measures, DOEII and eQuest. The Passive House Planning Package (PHPP), a write-in response, proved relatively popular among small firms (though not among respondents overall).

No analysis tool was used with a high degree of frequency: the average score was 1.21 on a scale of 1 to 5. Even Ecotect had an average score of only 1.86. A significant 45.8% of respondents reported that they never performed green building analysis on any project.

1.4 Satisfaction with Green Building Analysis Software

The strengths and weaknesses of existing green building analysis tools proved difficult to assess, and likely require further study. Most types of functionality (energy modeling, daylight modeling, etc.) received high importance ratings. However, satisfaction across all categories studied was middling at best (in the range of 2.5 to 3 out of 5) for all software programs, indicating large potential for improvement.

Overall, respondents showed the least satisfaction with areas of performance that can be broadly classified as “designer-friendliness,” including (1) learning curve, (2) ease of use, (3) customer service and support, (4) the ability to compare multiple design options, and (5) interoperability with 3-D modeling and BIM tools. In write-in responses, existing tools were often faulted for being overly complex and unintuitive. Respondents expressed slightly higher satisfaction with the reliability of results (3.17 of out 5), but lower levels of satisfaction at the ease of interpreting those results (3.08 out of 5). Among the top four tools, Vasari show the highest levels of satisfaction, while EnergyPlus OpenStudio showed the lowest—but even the highest ratings were approximately 3.4, indicating room for improvement.

The survey also revealed that existing analysis tools require a significant time investment to obtain results: 10 to 24 hours on average. This time investment may help to explain the low levels of adoption of green building analysis tools among architects.
2.0 Overview of Survey Respondents

One hundred seven (107) valid responses were collected, nearly equally split between professionals and current students. Professional respondents were largely junior and intermediate designers (Fig. 2.1).

There was a relatively even distribution of firm sizes among professional respondents, ranging from single-person firms to firms with more than 100 employees. Figure 2.2 compares the percent of professional respondents in each firm size category with the percent of firms in each category nationally, according to the AIA. Professional respondents were relatively evenly distributed among all firm size categories. Compared to national figures, this survey had a larger percent of respondents from the smallest firms (1 to 9 people), and relatively fewer respondents from the largest firms (100 and up).

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For most analysis purposes this survey looks at overall scores, as well as looking at differences between professionals and current students, between large firms and small firms, and, where relevant, between all respondents and those who report to be very familiar with green building and/or are frequent users of green building analysis tools. Small firms are defined as between 1 and 49 people; large firms are those with 50 or more employees. Using this taxonomy, small firms represented 68% of professional respondents, and large firms 32%—which means that results for small firms are apt to be more reliable than those for large firms.

No analysis has been undertaken to evaluate whether the sample of respondents to this survey are representative of all U.S. architects; indeed, it is likely that some degree of selection bias is present. This is particularly true for the “current student” respondents, who came from only a handful of architecture schools. (For more on survey methodology, see Appendix B.)
Respondents were asked several questions regarding their familiarity with green building practices, the frequency with which their firms engaged in green building, and their use of green building analysis tools. In general, familiarity and experience with green building far exceeded the use of analysis tools. For instance, 42% of respondents considered themselves familiar or very familiar with green building (4 or 5), but only 13% performed any kind of green analysis on a majority of their projects. Overall, very few respondents reported using analysis tools on a regular basis—a trend that was consistent among students and professionals, among large and small firms, among those who never engage in green building and those who considered themselves experts. In the absence of formal analysis, most practitioners are presumably relying on rules of thumb, prescriptive checklists, and/or consultants when engaging in green building—practices whose frequency and effectiveness merit further study.

3.1 Familiarity with Green Building

Respondents were asked to rate their familiarity with green building practices on a scale of 1 (not familiar at all) to 5 (an expert). Overall, the average response was 3.28, slightly tipped toward the “more familiar” end of the spectrum, with most respondents in the 3 to 4 range. Professional respondents reported higher levels of familiarity with green building practices than did students (Fig. 3.1). There was virtually no difference in familiarity between respondents from large vs. small firms (Fig. 3.2).

3.2 Frequency of Green Building

Respondents were asked to rate how frequently their firms engage in green building on a scale of 1 (never) to 5 (every project). Professional respondents reported that their firms very frequently engage in green building—indeed, fewer than 10% said that they “never” engage in green building. Large firms (50+ employees) are significantly more likely to engage in green building than small ones, with an average response of 3.94 (compared to 3.21 among small firms) (Fig. 3.3).
Green Building Practices

**FIG 3.1** FAMILIARITY WITH GREEN BUILDING PRACTICES

- **Overall**
- **Students**
- **Professionals**
- **Trendline (Overall)**

**FIG 3.2** FAMILIARITY WITH GREEN BUILDING PRACTICES - LARGE vs. SMALL FIRMS

- **Small Firms (1-49)**
- **Large Firms (50+)**
3.3 Frequency of Green Building Analysis

Respondents were asked: “In general, how frequently do you (personally) perform modeling or green building analysis? This includes energy modeling, daylight modeling, life cycle assessment, and the like.” Frequency was rated on a scale of 1 (never) to 5 (every project).

Most respondents (72%) reported that they never or rarely perform analysis of their designs (a rating of 1 or 2). Only 13% reported frequently or always performing some type of analysis (4 or 5) (Fig. 3.4). Students appear to be slightly more likely to perform analysis than professionals, and large firms appear to engage in analysis slightly more regularly than small firms (Fig. 3.5); however, these differences are not significant.¹

However, in response to a later question regarding the frequency of using specific green building analysis tools (see section 5.0: Green Building Analysis Tools), differences between small and large firms appear

¹ A plot of firm size vs. analysis frequency shows almost no correlation between the two variables. See Appendix C, Fig. C.16.
FIG 3.4 FREQUENCY OF PERFORMING GREEN BUILDING ANALYSIS

FIG 3.5 FREQUENCY OF GREEN BUILDING ANALYSIS - LARGE vs. SMALL FIRMS
more pronounced. The average frequency of using any such tools, on a scale of 1 to 5, was 1.17 among small firms and 1.35 among large firms.\textsuperscript{2} Both figures are meager, close to the “never” end of the spectrum, but large firms appeared to engage in analysis with slightly greater frequency.

Practices among students are often considered a bellwether for changes in architectural practice. Fewer students than professionals reported that they “never” performed any kind of green building analysis—32\% vs. 42\%, respectively—but there were also fewer students who frequently or always performed analysis (8\% vs. 18\%). Overall, the trend among students is similar to that among professionals. Like professionals, most students appear to be relying on alternative methods for designing green buildings—rules of thumb, checklists, or simply design by assertion.

3.4 Analysis & Design Phase

When green building analysis does occur, it tends to be in the early stages of the design process—most often during Conceptual or Schematic Design (Fig. 3.6). Those who report frequently performing such analysis are even more likely to do so in the earliest phases of design (Fig. 3.7).

3.5 Factors Affecting Analysis Frequency

Several factors were tested to see whether they had a relationship to the frequency of performing analysis. While some weak correlations between variables were found, none were considered to be significant. Specifically, the following relationships were tested:

1. **Green building familiarity vs. analysis frequency.** Do those more familiar with green building perform analysis more frequently? A weak positive correlation was found (Fig. C.14).

2. **Green building vs. analysis frequency.** Do firms that engage in green building more often perform analysis more frequently? A weak positive correlation was found (Fig. C.15).

3. **Firm size vs. analysis frequency.** Are larger or smaller firms more likely to perform analysis? No correlation was found (Fig. C.16).

\textsuperscript{2} These figures are based upon responses to listed software, not including write-in responses. When write-in responses are factored in, the averages become 1.15 for small firms, and 1.26 for large firms. Write-ins depress both averages because of the method used to quantify them (see Appendix B: Methodology), but the relationship is still visible.
**FIG 3.6** DESIGN PHASE IN WHICH ANALYSIS OCCURS

- Conceptual or Schematic Design: 56%
- Design Development: 38%
- Construction Documents or Construction Administration: 6%

**FIG 3.7** ANALYSIS DESIGN PHASE vs. ANALYSIS FREQUENCY

- Conceptual or Schematic Design
- Moderate to frequent modelers (3-5)
- People who model at all (2-5)
- Overall figures
- Design Development
- Construction Documents or Construction Administration
4. **Early-stage 3-D modeling tool vs. analysis frequency.** Are users of certain 3-D modeling and BIM tools more likely to perform analysis? Slight correlations were found among certain tools. The only program with a negative correlation was AutoCAD—i.e., those who frequently use AutoCAD in the early stages of design are slightly less likely to perform analysis (Fig. C.17).

5. **Primary green building analysis tool vs. analysis frequency.** Do users of certain analysis tools perform analysis more frequently? Slight correlations were found among certain tools. The strongest correlation was between Ecotect use and modeling frequency (Fig. C.18).

6. **Time required vs. analysis frequency.** Is a smaller time commitment correlated with increased analysis frequency? A very weak correlation was found (Fig. C.19). Note that the causal arrows could run in either direction here: increased familiarity with a tool could reduce the time required; alternatively, modest time requirements could prompt more frequent use.

Charts of all of these relationships are available in Appendix C.
Respondents were asked to rate the frequency with which they used a variety of 3-D modeling and/or BIM tools in the early stages of the design process (conceptual or schematic design). Respondents could also write in additional tools. These write-in responses were quantified as described in Appendix B.

The most-used early-stage 3-D modeling and BIM platforms appear to be, in order: (1) Google SketchUp, (2) Autodesk AutoCAD, (3) Autodesk Revit, and (4) Rhino (Figures 4.1 and 4.2). Autodesk’s 3ds Max also appears to be used frequently, particularly given that it was a write-in response. Large firms (50+ employees) overwhelmingly prefer Revit, while small firms eschew it; and small firms (1 to 49 employees) use AutoCAD most frequently. Current students use AutoCAD less.

**Fig 4.1** FREQUENCY OF USE AMONG EARLY-STAGE 3-D MODELING & BIM TOOLS

<table>
<thead>
<tr>
<th>Tool</th>
<th>Frequency of Use</th>
<th>Average</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Autodesk AutoCAD</td>
<td>4.5</td>
<td>3.5</td>
<td>1.0</td>
</tr>
<tr>
<td>Autodesk Revit</td>
<td>4.2</td>
<td>3.8</td>
<td>1.2</td>
</tr>
<tr>
<td>Bentley Architecture</td>
<td>3.8</td>
<td>3.5</td>
<td>1.0</td>
</tr>
<tr>
<td>Bentley MicroStation</td>
<td>2.5</td>
<td>2.3</td>
<td>0.8</td>
</tr>
<tr>
<td>Google SketchUp</td>
<td>2.0</td>
<td>2.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Graphisoft ArchiCAD</td>
<td>2.0</td>
<td>2.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Rhino</td>
<td>1.8</td>
<td>1.8</td>
<td>1.0</td>
</tr>
<tr>
<td>Bonza3d (Write-in)</td>
<td>1.5</td>
<td>1.5</td>
<td>1.0</td>
</tr>
<tr>
<td>3DS Max (Write-in)</td>
<td>1.5</td>
<td>1.5</td>
<td>1.0</td>
</tr>
<tr>
<td>Maya (Write-in)</td>
<td>1.5</td>
<td>1.5</td>
<td>1.0</td>
</tr>
</tbody>
</table>
Early-Stage Modeling Software

**Figure 4.2** FREQUENCY OF USE AMONG MODELING & BIM TOOLS - STUDENTS vs. PROFESSIONALS

**Figure 4.3** FREQUENCY OF USE AMONG MODELING & BIM TOOLS - LARGE vs. SMALL FIRMS

- *Students* and *Professionals* are compared for each tool.
- *Small Firms* (1-49) and *Large Firms* (50+) are compared for each tool.

<table>
<thead>
<tr>
<th>Tool</th>
<th>Overall</th>
<th>Students</th>
<th>Professionals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Autodesk AutoCAD</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td></td>
<td></td>
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<tr>
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<tr>
<td>Maya (Write-in)</td>
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<tr>
<td>Autodesk AutoCAD</td>
<td>3.00</td>
<td>3.50</td>
<td>2.50</td>
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<tr>
<td>Autodesk Revit</td>
<td>2.50</td>
<td>3.00</td>
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</tr>
<tr>
<td>Bentley Architecture</td>
<td>2.00</td>
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<td>1.50</td>
</tr>
<tr>
<td>Bentley MicroStation</td>
<td>1.50</td>
<td>2.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Google SketchUp</td>
<td>1.00</td>
<td>1.50</td>
<td>0.50</td>
</tr>
<tr>
<td>Graphisoft ArchiCAD</td>
<td>0.50</td>
<td>1.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Rhino</td>
<td>4.00</td>
<td>3.50</td>
<td>3.00</td>
</tr>
<tr>
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<td>3.00</td>
<td>2.50</td>
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<td>2.00</td>
</tr>
<tr>
<td>Maya (Write-in)</td>
<td>2.50</td>
<td>2.00</td>
<td>1.50</td>
</tr>
</tbody>
</table>

**Frequency of Use (1 = never, 5 = every project)**

- Small Firms (1-49) vs. Large Firms (50+)

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**FREQUENCY OF USE AMONG MODELING & BIM TOOLS - STUDENTS vs. PROFESSIONALS**

**FREQUENCY OF USE AMONG MODELING & BIM TOOLS - LARGE vs. SMALL FIRMS**
frequently and SketchUp more frequently than professionals; students also account for 100% of the write-in votes for Autodesys Bonzai 3d.

All programs show a large standard deviation (shown in Fig. 4.1), indicating a high degree of spread among responses. For any given software, responses typically included plentiful amounts of both 1’s (never) and 5’s (always). This suggests that designers tend to choose one or two favored programs and ignore the rest. (For more detailed data on software use, see Appendix C.)

Among the top three programs (SketchUp, AutoCAD, and Revit), SketchUp had the lowest standard deviation, as well as the lowest percentage of 1 (never) responses (12%) and the highest percentage of mid-range (2 to 4) responses (52%). By comparison, Revit had the highest percentage of 1 (never) responses (32%) and the lowest percentage of mid-range (2 to 4) responses (43%). In other words, SketchUp is the software that is most likely to be used in some capacity by nearly all demographics studied: practicing professionals, current students, and frequent modelers. The only exception is large firms, which show a clear preference for Revit. (See also Appendix C, Fig. C.1.)
Early-Stage Modeling Software
Respondents were asked to rate the frequency with which they used a variety of green building analysis tools, including a number of energy modelers, daylight modelers, life cycle assessment tools, and multi-functional programs. Respondents could also write in additional programs. In addition, respondents were asked to rate the importance of various features and functionality in an analysis tool, and to rate their satisfaction with their primary analysis tool across a number of dimensions.

Four basic findings stand out as particularly significant.

1. **Autodesk Ecotect is the most used analysis tool** by all measures, among all demographics, and by a large margin.
FIG 5.2  FREQUENCY OF USE AMONG GREEN ANALYSIS TOOLS - STANDARD DEVIATION

FIG 5.3  FREQUENCY OF USE AMONG GREEN ANALYSIS TOOLS - STUDENTS vs. PROFESSIONALS
2. **No analysis tool is used with a high degree of frequency.** The average score among all programs was 1.21 on a scale of 1 to 5—vanishingly close to the “never” end of the spectrum (with 5 representing using a tool on “every project”). This was true even for Ecotect, which had an average score of 1.86. When asked to select a primary analysis tool, 45.8% of respondents selected the option “None—I don’t perform green building analysis.”

3. **The time required to obtain results is in the range of 10 to 24 hours**—or 1.25 to 3 workdays—with an overall average of 11.14 hours. This may help to explain the rare use of these tools: in a fast-paced design environment, where iterations are rapid, the time required to test iterations with existing tools is simply too great. By the time results are in, the design team has moved on.

4. **Satisfaction with existing tools is middling at best,** in the 2.5 to 3 range (on a scale of 1 to 5). Users seem to be dissatisfied even with aspects of performance that they consider very important, such as interoperability and ease of use.

### 5.1 Preferred Software

The use of green building analysis software was assessed in two ways. First, respondents were asked to rate the frequency with which they used various tools. Second, respondents were asked to choose their primary analysis tool.

The top three most frequently used tools were, in order: (1) Autodesk Ecotect, (2) Autodesk Vasari, and (3) EnergyPlus OpenStudio. The top three primary analysis tools were, in order: (1) Autodesk Ecotect, (2) Autodesk Vasari, and tied for third, EnergyPlus OpenStudio and Autodesk Green Building Studio. In both cases, Ecotect came out on top by a large margin, and the differences between the remaining tools were much less significant (see Figures 5.1 and 5.2).

The standard deviation among green building analysis tools is very large—even larger than among early-stage 3-D modeling and BIM software (Figures 5.1 and 5.2). The large spread of responses likely has similar roots as modeling software: designers choose a small number of tools that they use regularly. However, the results suggest that, aside from Ecotect, designers are often choosing different tools: the large standard deviation makes it difficult to differentiate between the remaining software.

#### 5.1.1 Frequency of Use

Ecotect is used even more frequently among students than professionals; and both DOEII/eQuest and EnergyPlus OpenStudio are used with relatively high frequency among professionals (at a rate
FIG 5.4 FREQUENCY OF USE AMONG GREEN ANALYSIS TOOLS - LARGE vs. SMALL FIRMS

FIG 5.5 FREQUENCY OF USE AMONG GREEN ANALYSIS TOOLS - GREEN DESIGNERS
approaching professionals’ use of Vasari) (Fig. 5.3). Large firms engage in analysis more frequently than small firms (with average ratings of 1.35 and 1.17, respectively); specifically, large firms tend to use Green Building Studio, DOEII / eQuest, Ecotect, and OpenStudio with much greater frequency than do small firms. Small firms, on the other hand, show a distinct predilection for the Passive House Planning Package, and to a lesser extent, AGI132 (both write-in responses whose use is probably understated) (Fig. 5.4). Frequent modelers show a clear preference for Ecotect and Vasari, and, to a lesser extent, Passive House Planning Package and Climate Consultant (both write-in responses) (Fig. 5.5).  

5.1.2 Primary Tool

An overwhelming 31.8% of respondents consider Ecotect their primary analysis tool; Vasari follows at a distant second with 5.6%, and OpenStudio and Green Building Studio are tied for third at 2.8% (Fig. 5.6). These results are roughly consistent with the frequency of use data. Passive House Planning Package and Trane Trace scored relatively better than the frequency data suggested, and DOEII / eQuest relatively worse; however, the differences among these tools are really too small to be conclusive. Nearly half (46.8%) of respondents chose the option “None—I don’t perform green building analysis.”

Aside from Ecotect, large and small firms show markedly different preferences for primary analysis tools. Large firms are much more likely to use Green Building Studio primarily, whereas no small firm considered this their primary tool. Vasari, which rated highly in other measures, is rarely considered a “primary tool” among professionals, and not at all among large firms. Small firms show a greater diversity in primary tool choice than do large firms.

5.2 Differences in Use Among Primary Analysis Tools

To investigate differences in use among primary tools, a number of correlations were investigated.

1. **Analysis frequency vs. primary analysis tool use.** Is use of a particular tool correlated with increased modeling frequency? Slight correlations were found among certain tools. The

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1. These figures are based upon responses to listed software, not including write-in responses (see Section 3, note 2).
2. People who responded with a 4 or 5 to the question “In general, how frequently do you (personally) perform green building modeling or analysis?”
3. Climate Consultant is not a green building analysis tool in the strict sense of the term, since it does not assess specific building designs. It is included because it was frequently given as a write-in response.
FIG 5.6 PRIMARY GREEN BUILDING ANALYSIS TOOL

FIG 5.7 PRIMARY GREEN BUILDING ANALYSIS TOOL - LARGE vs. SMALL FIRMS
strongest correlation was between Ecotect use and modeling frequency (Fig. C.18).

2. **Green building vs. primary analysis tool use.** Is increased frequency of green building correlated with increased use of a particular tool among professionals? Slight correlations were found among several tools (Figure C.20). The strongest correlation, while still slight, was between frequency of Ecotect use and green building. This correlation may be in part attributable to the fact that designers of green buildings are more apt to perform analysis than their conventional counterparts; however, the correlation is stronger than the one found between green building frequency and analysis tool use overall—so other factor(s) must be at work. This may include Ecotect’s popularity among large firms, which engage in green building and perform analysis more frequently than small firms.

3. **Analysis tool use vs. firm size.** Are certain tools significantly more popular among large or small firms? (Unlike previous analyses, this allowed for a gradation of firm size, instead of arbitrarily dividing firms at 50 employees.) No significant correlations were found (Figure C.21).

Charts of all of these relationships are available in Appendix C.

### 5.3 Important Features

Respondents were asked to rate the importance of a number of features in a green building analysis tool. Respondents could also write in features that were not listed.

On average, all features listed scored between 3 and 5 on a scale of 1 to 5—in other words, all were considered at least moderately important, and there were few clear winners and losers (Fig. 5.8). This is true even when looking only at the responses of those who frequently perform green building analysis (Fig. 5.10). The clearest winners involved ease of use rather than specific functionality: “easy to understand results” and “ability to use existing BIM or 3-D models” ranked very high across all demographics.

Overall, the top features (with an average score of 4 or higher) are, in order: (1) easy to understand results, (2) ability to use existing BIM or 3-D models to generate results, (3) daylight modeling, and (4) energy modeling. The lowest-ranked features (a score of 3.5 or lower) are: (1) automatic benchmarking (e.g., against EnergyStar, ASHRAE, etc.), (2) LEED compliance calculations, (3) sizing of mechanical systems, and (4) computational fluid dynamics (CFD) or precise ventilation studies—however, even these “low” scorers were in the 3.3 to 3.5 range.
Figure 5.8 IMPORTANCE OF FEATURES IN A GREEN ANALYSIS TOOL

Figure 5.9 IMPORTANCE OF FEATURES IN A GREEN ANALYSIS TOOL - STUDENTS vs. PROFESSIONALS
The ratings are relatively similar between students and professionals. In general, students rated features higher than professionals, with the exception of automatic benchmarking, which professionals rated higher (Fig. 5.9). The most substantial differences between professionals and students were in the areas of Life Cycle Assessment, water use calculations, renewable energy calculations, and CFD / precise ventilation studies, with students rating these higher than professionals in each case.

Ratings were not significantly different between small and large firms, or between junior and senior designers. (Charts not shown.)

Frequent modelers found energy modeling, cost / payback calculations, and detailed shading design to be more important than overall respondents; and they found renewable energy calculations, visualization of climate and weather data, and daylight modeling to be less important. However, most of the differences are relatively subtle (Fig. 5.10).

The most popular write-in responses involved various factors relating to ease of use and/or design integration. Some typical examples to the prompt “please list any other features you consider very important” included:

- “User-friendliness.”
- “Easy to model.”
SATISFACTION WITH GREEN ANALYSIS TOOLS (OVERALL)

SATISFACTION WITH PRIMARY GREEN ANALYSIS TOOLS

FIG 5.11

FIG 5.12

Satisfaction with Green Building Tools (Overall)
“The software must be able to use existing models, but it must also be easy to model and work in.”

“Simple integration / simple output.”

“An all-in-one program would be very beneficial.”

“Well-designed user interface is very important.”

“The ability to compare different design schemes with ease would be convenient.”

The prevalence of such responses indicates that ease of use and integration into the standard design process is extremely important for green building analysis tools.

5.4 Satisfaction with Primary Tools

Respondents were asked to rate their satisfaction with their primary analysis tool across a range of categories. Satisfaction levels of the four most popular primary tools—Ecotect, Vasari, Green Building Studio, and EnergyPlus OpenStudio—are shown in Fig. 5.12. The results for Green Building Studio and OpenStudio are based on a small number of responses, and therefore have a high level of uncertainty.

Overall, levels of satisfaction are middling at best, ranging from 2.3 to 3.3 on a scale of 1 to 5 (Figure 5.11). Among the top four primary tools, Vasari had the highest levels of satisfaction in every category except for “accuracy / reliability of results;” OpenStudio had the lowest levels of satisfaction, except for “learning curve” and “accuracy of results.”

In a more open-ended evaluation of satisfaction, respondents were asked what they liked most about their primary tool, and what was missing. Among the four most popular primary tools, often-mentioned strengths included the capabilities of the programs and their ability to generate robust and reliable data. Where interoperability was available, this was considered a strength (for instance, OpenStudio’s SketchUp plug-in, or Vasari’s compatibility with Revit). Typical complaints were that the programs were difficult to use, were not intuitive, and were too complex for the average designer and/or early stages of design. Ecotect was faulted for poor interoperability with 3-D modelers and BIM tools (SketchUp, Revit, and Rhino were mentioned specifically.) These responses reaffirm the low satisfaction with “ease of use” and “interoperability.”

5.4.1 Satisfaction vs. Importance

Whereas ease of use appears to be extremely important to users of analysis tools, satisfaction with existing tools in this area is particularly low. More specifically, easy-to-understand results and interoperability were rated as extremely important features across all demographics; write-in responses suggest that ease of use more generally may be
FIG 5.13  IMPORTANCE vs. SATISFACTION OF SELECT FEATURES

- Interoperability: Average Importance 4.37, Average Satisfaction 3.02
- Easy to understand results: Average Importance 4.70, Average Satisfaction 3.08
- Ease of use: Average Importance 3.85, Average Satisfaction 2.84

FIG 5.14  TIME REQUIRED FOR RESULTS

- Ecotect: Average Time Required for Analysis 20 hrs
- Vasari: Average Time Required for Analysis 30 hrs
- Green Building Studio: Average Time Required for Analysis 40 hrs
- EnergyPlus: Average Time Required for Analysis 50 hrs
equally important. However, satisfaction with existing tools in these areas appears to be relatively low, as shown in Figure 5.13. In other words, some of the most important features of green building analysis tools are not yet performing satisfactorily.

A few words of caution about Figure 5.13: First, the column “interoperability” compares results from two categories: “ability to use existing 3-D or BIM models” (importance), and “compatibility with other programs” (satisfaction). Second, the importance of “ease of use” was not evaluated quantitatively in the survey. In Figure 5.13, the importance rating is assumed to be the average for all features evaluated (3.85)—but could easily be as high as (or higher than) the rating for “easy to understand results.” In either case, there is a marked difference between importance and satisfaction in this area.

5.5 Time Required for Results

The time required to get results from green building analysis tools is significant: average time investment reported by respondents was between 10 and 24 hours—or 1.25 to 3 workdays—with an overall average of 11.1 hours. Of the four most popular primary tools, Ecotect had the shortest average time (10.2 hours), while Green Building Studio had the longest (23.7 hours).

Does the time required diminish as a practitioner uses a tool more frequently, becoming more familiar with the software and surmounting the steepest part of the learning curve? Surprisingly, the answer appears to be no. A plot of modeling frequency vs. time required (Figure C.19) shows only the slightest correlation between the two variables. The length of time required to obtain results appears to be inherent to the tools themselves.

The large time requirements may help to explain the rare use of these tools. There are likely a number of factors that contribute to the low levels of adoption of green building analysis tools, and further research is needed to isolate these factors. However, time investment appears consistently in available literature as a major barrier to frequent, iterative green building analysis during design, and this survey seems to support this thesis.

There is much room for growth in the field of green building analysis tools—both in terms of the tools themselves, which are largely unsatisfactory and time-consuming, and in terms of the overall architecture industry, which has not yet embraced green building analysis software on a wide scale.
Green Building Analysis Software
6.0 Further Research

This survey has provided an overview of general preferences in software use and certain green building practices among U.S. architects. It has also raised additional questions. A few areas for further study include:

1. What importance do practitioners assign to green building analysis? Do they consider it an essential part of designing green buildings? Do views vary by demographic?

2. For those firms who currently engage in green building but do not frequently use analysis software, what are the alternatives to formal analysis? These likely include consultants, rules of thumb, and prescriptive checklists. What do they see as the strengths and weaknesses of each alternative?

3. What is the biggest obstacle to performing analysis more frequently? Lack of interest? Expense? Time commitment? Expertise? Or other factors entirely?

4. For those who do perform analysis frequently, what provides the motivation to do so?

5. What types of analysis are being performed most often, and at what stages of design? How does current practice different from the ideal?

These topics could help to clarify and extend the conclusions reached in this survey.
Further Research
7.0 Biographical Note

Carl S. Sterner, LEED AP, is the owner of Sterner Design, a New York based sustainable design and consulting practice. Prior to establishing Sterner Design, Carl worked for a number of design firms across the U.S., including at the internationally recognized architecture firm William McDonough + Partners. His design work has centered on high-ambition sustainable projects, including net-zero or net-positive buildings, multiple LEED Platinum and Gold projects, and award-winning competition entries. Carl publishes frequently on sustainability issues, and was recently featured in the peer-reviewed volume *New Directions in Sustainable Design* (Routledge, 2011). His current research centers on early-stage environmental analysis—incorporating Life Cycle Assessment, energy modeling, and other analyses in the earliest phases of design.

This report describes a survey that was undertaken as part of the development of an early-stage green building analysis tool, tentatively named The Green Dashboard. Those interested in learning more about The Green Dashboard should email carl@sternerdesign.com.

For more on Carl’s work, please visit www.carlsterner.com and www.sternerdesign.com.
Thanks for taking this short (5-minute) survey! It is intended for architects, architectural designers, and students of architecture, and asks about current design tools and practices in the area of sustainable design. Your answers will help guide the development of a new sustainable design software tool.

To show our appreciation, we’re offering to share the results of the survey when they’re available (anonymized, of course). You’ll have a chance to sign up at the end of the survey.

Finally, please send this survey to your friends and colleagues! The more people who take it, the better the results will be.
Architecture Software Survey

User Info - Page 1 of 5

Position / Job Title *
Titles vary by firm; please choose the most applicable option.
- Current student
- Student Intern (temporary position)
- Junior Architect / Designer
- Intermediate Architect / Designer
- Senior Architect / Designer
- Project Manager
- Partner / Owner
- Other: [ ]

How many people work at your firm?
# of employees
Please select

How familiar are you with green building practices?

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
</table>

What's that?  0 0 0 0 5 I wrote the book on it.

How frequently does your firm engage in “green building”?

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
</table>

Never 0 0 0 0 0 Every Project

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## Architecture Software Survey

* Required

### Software Tools - Page 2 of 5

How often do you (personally) use the following 3d modeling or BIM software in the early stages of design?

Early stages of design = programming, conceptual design, or schematic design

<table>
<thead>
<tr>
<th>Software</th>
<th>1 (Never)</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5 (Every Project)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Autodesk AutoCAD</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Autodesk Revit</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bentley Architecture</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bentley MicroStation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Google SketchUp</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Graphisoft ArchiCAD</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rhino</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Is there another 3d modeling or BIM software you use often?

Did we miss one?
How often do you (personally) use the following green building analysis tools?

<table>
<thead>
<tr>
<th>Tool</th>
<th>1 (Never)</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5 (Every Project)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Athena Eco-Calculator or Impact Estimator</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Autodesk Ecotect</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Autodesk Green Building Studio</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Autodesk Vasari</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DesignBuilder</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DOEII or eQuest</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EnergyPlus (including Open Studio plugin)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Integrated Environmental Solutions (IES) VE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radiance or DAYSIM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Is there another analysis tool you use often?
Did we miss one?

In general, how frequently do you (personally) perform modeling or green building analysis? *
This includes energy modeling, daylight modeling, life cycle assessment, and the like.

1 2 3 4 5

Never  Every Project
Which tool do you use MOST OFTEN for green building analysis? *

- Athena Eco-Calculator or Impact Estimator
- Autodesk Ecotect
- Autodesk Green Building Studio
- Autodesk Vasari
- DesignBuilder
- DOEII or eQuest
- EnergyPlus (including OpenStudio plugin)
- Integrated Environmental Solutions (IES) VE
- Radiance or DAYSIM
- None - I don’t do green building analysis. (You may skip to the next page.)
- Other: [text box]

Thinking of your primary analysis tool, when do you most often use it?

- Conceptual or Schematic Design
- Design Development
- Construction Documents or Construction Administration
- Other: [text box]

On average, how long does it take to generate meaningful results?

[Please select]

Thinking of your primary analysis tool, how satisfied are you with its performance in the following areas?

1 (Not at all satisfied)
2 3 4 5 (Extremely satisfied)

- Ease of use
- Learning curve (1 = slow, 5 = fast)
- Accuracy / reliability of results
- Ease of interpreting results
- Time investment to get results (1 = long, 5 = short)
- Ability to compare multiple options or design schemes
- Compatibility with other programs
- Customer service & support

What do you like most about it?
Thinking of your primary analysis tool, how satisfied are you with its performance in the following areas?

<table>
<thead>
<tr>
<th></th>
<th>1 (Not at all satisfied)</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5 (Extremely satisfied)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ease of use</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Learning curve (1 = slow, 5 = fast)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accuracy / reliability of results</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ease of interpreting results</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time investment to get results (1 = long, 5 = short)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ability to compare multiple options or design schemes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compatibility with other programs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Customer service &amp; support</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

What do you like most about it?
What is missing?

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## Features - Page 4 of 5

### How important are the following features in a green building analysis tool? *

<table>
<thead>
<tr>
<th>Feature</th>
<th>1 (Not at all important)</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5 (Must have!)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy modeling</td>
<td>Ø</td>
<td>Ø</td>
<td>Ø</td>
<td>Ø</td>
<td>Ø</td>
</tr>
<tr>
<td>Life Cycle</td>
<td></td>
<td>Ø</td>
<td>Ø</td>
<td>Ø</td>
<td>Ø</td>
</tr>
<tr>
<td>Assessment of building materials</td>
<td></td>
<td>Ø</td>
<td>Ø</td>
<td>Ø</td>
<td>Ø</td>
</tr>
<tr>
<td>Daylight modeling</td>
<td>Ø</td>
<td>Ø</td>
<td>Ø</td>
<td>Ø</td>
<td>Ø</td>
</tr>
<tr>
<td>Water use calculations</td>
<td></td>
<td>Ø</td>
<td>Ø</td>
<td>Ø</td>
<td>Ø</td>
</tr>
<tr>
<td>Feature</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>---------------------------------------------</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Rainwater capture calculations</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Renewable energy calculations</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Cost estimates / payback calculations</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Detailed shading design</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>CFD / precise ventilation studies</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Visualization of climate &amp; weather data</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Sizing of mechanical systems</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>LEED compliance calculations</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Automatic benchmarking (e.g., against EnergyStar, ASHRAE Appx. G, etc.)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Ability to use existing 3d or BIM models for analysis</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Easy to understand results</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Please list any other features that you consider very important.
We're in the process of developing an easy-to-use green building analysis tool. If you're interested in learning more about this project, please join our mailing list by entering your email below.

**Email address for newsletter:**
By providing your email, you are subscribing to our mailing list. We will not share your information, and you may unsubscribe at any time.

If you would like to see the results of this survey when they become available, please provide your email address below. A report will be emailed to you at a later date.

**Email address for survey results:**
This email will ONLY be used to send survey results.
Appendix B
Methodology

Results were collected between October 18 and October 31, 2011. The survey was implemented via the Google Docs “Forms” feature. A non-monetary incentive was offered: respondents could opt to receive a copy of this report. One hundred seven (107) valid responses were collected, nearly equally split between professionals and current students. (For a detailed breakdown of survey respondents, see section 2.0: Overview of Survey Respondents.)

The survey was distributed through the author’s network of personal contacts, including colleagues, friends, and former classmates. In addition, the author asked respondents to forward the survey to their colleagues. This yielded a seemingly diverse group of respondents, as described in section 2.0. However, no analysis has been undertaken to evaluate whether the sample is representative of all U.S. architects; indeed, it is likely that some degree of selection bias is present. This is particularly true for the “current student” respondents, who came from only a handful of architecture schools—primarily University of Virginia, Virginia Tech, Miami University of Ohio, and University of Cincinnati.

The majority of questions used a 1 to 5 rating scale, with 1 being a low ranking (never / strongly disagree) and 5 being a high ranking (always / strongly agree). Write-in responses were allowed for a number of questions—particularly those that asked respondents to choose most-used software programs.

Quantifying write-in responses, however, proved challenging, because there was simply no data for a majority of respondents. For instance, when asked about most-used 3-D modeling or BIM tools, a number of respondents wrote in “3ds Max”—but the large majority of respondents provided no information whatsoever on 3ds Max. It is difficult to ascertain how these respondents would have rated the software had it been listed as a primary option.

The charts shown in this survey quantified write-in responses using the following methodology. A write-in response was assigned a high rating (5)—considered appropriate because questions typically prompted respondents to write in answers that they considered important or significant. The remaining respondents (in the above example, the majority who did not write in “3ds max”) were assigned a low value (1). This
approach likely under-estimates the popularity of these write-in programs: had they appeared as primary options on the survey, some of the 1's would most certainly have been bumped up to 2's or 3's. In other words, the popularity of tools such as 3ds Max and the Passive House Planning Package are likely understated. Where write-in responses are shown on graphs, they are identified as such.
Appendix C
Detailed Survey Results

Use of early-stage 3-D modeling and BIM software

**Fig C.1** USE FREQUENCY OF VARIOUS 3-D MODELING AND BIM TOOLS

(a) Autodesk AutoCAD

(b) Autodesk Revit

(c) Bentley Architecture

(d) Bentley Microstation

(e) Google SketchUp

(f) Graphisoft ArchiCAD

(g) Rhino
Analysis tool use among various demographics

Fig C.2  USE OF ANALYSIS TOOLS OVERALL

Fig C.3  USE OF ANALYSIS TOOLS AMONG THOSE FAMILIAR WITH GREEN BUILDING (4 - 5)
Figure C.4: USE OF ANALYSIS TOOLS AMONG FREQUENT GREEN BUILDERS (4 - 5)

Figure C.5: USE OF ANALYSIS TOOL AMONG THOSE WHO FREQUENTLY PERFORM ANALYSIS (4 - 5)
Primary analysis tool among various demographics

FIG C.6 PRIMARY ANALYSIS TOOL (OVERALL)

- Other: 3.7%
- AGI32: 0.9%
- Radiance or DAYSIM: 0.9%
- DOEII or eQuest: 0.9%
- IES-VE: 0.9%
- Trane Trace: 1.9%
- PHPP: 1.9%
- Green Bldg Studio: 2.8%
- EnergyPlus: 2.8%
- Vasari: 5.6%
- Ecotect: 31.8%

FIG C.7 PRIMARY ANALYSIS TOOL AMONG STUDENTS

- Other: 4.0%
- AGI32: 0.0%
- Radiance or DAYSIM: 0.0%
- DOEII or eQuest: 0.0%
- IES-VE: 0.0%
- Trane Trace: 0.0%
- PHPP: 0.0%
- Green Bldg Studio: 0.0%
- EnergyPlus: 2.0%
- Vasari: 4.0%
- Ecotect: 44.0%
FIG C.8 PRIMARY ANALYSIS TOOL AMONG PROFESSIONALS

- Other: 3.9%
- AGI32: 0.0%
- Radiance or DAYSIM: 2.0%
- DOEII or eQuest: 2.0%
- IES-VE: 2.0%
- Trane Trace: 3.9%
- PHPP: 3.9%
- Green Bldg Studio: 5.9%
- EnergyPlus: 2.0%
- Vasari: 5.9%
- Ecotect: 21.6%

FIG C.9 PRIMARY ANALYSIS TOOL AMONG THOSE WHO FREQUENTLY PERFORM ANALYSIS

- Other: 7.1%
- AGI32: 0.0%
- Radiance or DAYSIM: 0.0%
- DOEII or eQuest: 0.0%
- IES-VE: 0.0%
- Trane Trace: 7.1%
- PHPP: 14.3%
- Green Bldg Studio: 7.1%
- EnergyPlus: 7.1%
- Vasari: 14.3%
- Ecotect: 35.7%
Satisfaction with primary tools

**SATISFACTION WITH ECOTECT**

![Graph showing satisfaction with Ecotect](image)

**SATISFACTION WITH VASARI**

![Graph showing satisfaction with Vasari](image)
SATISFACTION WITH ENERGYPLUS OPENSTUDIO

FIG C.12

SATISFACTION WITH GREEN BUILDING STUDIO

FIG C.13
Factors affecting analysis frequency

Several factors were tested to see if they had any relationship to the frequency with which respondents performed green building analysis. These relationships are shown in the graphs that follow.

FAMILIARITY WITH GREEN BUILDING vs. ANALYSIS FREQUENCY

FIG C.14
GREEN BUILDING FREQUENCY vs. ANALYSIS FREQUENCY

fig c.15

\[ y = 0.36x + 0.88 \]

\[ R^2 = 0.1266 \]
FIG C.16  FIRM SIZE vs. ANALYSIS FREQUENCY

R² = 0.003
FIG C.17  EARLY-STAGE 3-D MODELING TOOL USE vs. ANALYSIS FREQUENCY

- Modeling Frequency vs. AutoCAD
- Modeling Frequency vs. Revit
- Modeling Frequency vs. SketchUp
- Modeling Frequency vs. Rhino
- Modeling Frequency vs. 3D Studio Max
- Modeling Frequency vs. Bonzai
FIG C.18 PRIMARY GREEN BUILDING ANALYSIS TOOL USE vs. ANALYSIS FREQUENCY

- Modeling Frequency vs. Ecotect
- Modeling Frequency vs. Vasari
- Modeling Frequency vs. EnergyPlus
- Modeling Frequency vs. Athena Impact Estimator
- Modeling Frequency vs. DOEII / eQuest
- Modeling Frequency vs. PHPP
- Modeling Frequency vs. Climate Consultant
FIG C.19 TIME REQUIRED vs. ANALYSIS FREQUENCY

Frequency of Modeling
(0 = never, 5 = every project)

$R^2 = 0.017$
Differences in use among primary analysis tools

Several factors were tested to see if they had any relationship to the use of primary green building analysis tools. These relationships are shown in the graphs below. Figure C.18, Primary Green Building Analysis Tool vs. Analysis Frequency, is also relevant.

**FIG C.20**  GREEN BUILDING FREQUENCY vs. PRIMARY GREEN BUILDING ANALYSIS TOOL USE
**FIG C.21**  FIRM SIZE vs. PRIMARY GREEN BUILDING ANALYSIS TOOL USE

- **Firm Size vs. Athena IE or Eco-Calc**: 
  \[ R^2 = 0.0006 \]

- **Firm Size vs. Ecotect**: 
  \[ R^2 = 0.0252 \]

- **Firm Size vs. Green Building Studio**: 
  \[ R^2 = 0.1226 \]

- **Firm Size vs. Vasari**: 
  \[ R^2 = 0.0032 \]

- **Firm Size vs. DOEII / eQuest**: 
  \[ R^2 = 0.0717 \]

- **Firm Size vs. EnergyPlus**: 
  \[ R^2 = 0.0717 \]