

Women as Sustainability Leaders in Engineering: Evidence from Industry and Academia*

JENNILEE HARRISON and LEIDY KLOTZ

Clemson University Department of Civil Engineering, Lowry Hall, Clemson, SC 29634, USA.

E-mail: jennilh@clemson.edu, leidyk@clemson.edu

Women are underrepresented in engineering education and practice, which limits the quality of the engineering workforce. One way to increase the participation of women in engineering is to emphasize subjects that appeal to them and require skills at which they are especially adept. A subject that may fit this description is sustainability. To examine whether the subject of sustainability may help increase the participation of women in engineering, the purpose of this research is to compare the percentage of women in selected sustainable engineering leadership positions with the percentage of women in general engineering leadership positions. Gender data were collected for the 'sustainability leader' at 79 of the largest design and construction companies in the U.S. Similar data were also compiled for engineering faculty attending workshops to share best practices for teaching sustainability. The percentage of women in the sustainability leader industry positions is much higher (39%) than the percentage of women in general management positions (8%). The percentage of woman attending the workshops is much higher (32%) than the percentage of woman engineering faculty (12%). Analysis of these results shows a statistically significant positive correlation between the subject of sustainability and increased percentages of women in engineering leadership positions. Increased consideration of sustainability in engineering education and practice could also help address the critical need to attract more women to the field.

Keywords: sustainability; women; gender; leadership

1. INTRODUCTION

DESPITE ACHIEVING EQUAL REPRESENTATION in other professions, women remain seriously underrepresented in engineering. This inhibits the development of the profession [1]. One way to increase the participation of women in engineering is to emphasize subjects that align with their interests and skills. The literature provides compelling anecdotal evidence that sustainability: 'meeting humans' social, environmental, and economic needs without compromising the ability of future generations to do the same', is one such subject that may be especially appealing to women [2, 3]. Still, additional studies are needed to examine any relationship between sustainability and increased participation of women in engineering. To begin addressing this need, the objective of this research is to compare the percentage of women in selected sustainable engineering leadership positions with the percentage of women in general engineering leadership positions.

Pursuit of this objective involved data collection from selected groups in industry and academia. The top 100 design firms and top 100 construction companies in the U.S. were surveyed to gather

gender-related information for the individual leading sustainability efforts at that company. In addition, similar information was collected for engineering faculty attending workshops to share best practices for teaching sustainable engineering. In both cases, the percentage of women in these sustainability leadership positions is significantly higher than the percentage of women in comparable leadership positions. These findings support the theory that increased consideration of sustainability in engineering education and practice can help address the critical need to attract more women to the field.

2. BACKGROUND

From a young age, women face barriers to pursuing engineering. For example, primary school experiences lead young girls to view the physical sciences as more masculine and the life sciences as more feminine [4]. The problem persists into middle school, where it is common for girls to lose interest in both science and math classes [5]. In High School, girls take fewer Advanced Placement Mathematics and Science courses than boys. Though this gap in course enrollment is shrinking, a prevailing misconception is that boys significantly outperform girls in these courses [6]. Prior

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to college, young women receive minimal encouragement to pursue engineering and often lack role models in the field [7].

The consequence of these and other barriers is disproportionately low enrollment of women in engineering degree programs. In 2008, just 18% of engineering bachelor's degrees were awarded to women [8]. Further, despite efforts to attract more women to engineering, the most recent data shows a 3% decrease in the percentage of women receiving engineering degrees over the last 10 years [8]. Consequently, while other professions, including medicine and law, have achieved equal representation of women, engineering remains a predominantly male field [9, 10].

Attracting more women will help the field of engineering improve capabilities in crucial skills at which women are generally more adept than men. For instance, women excel in group affiliation skills, such as integration and collaboration [11, 12]. Though essential for engineers, these skills are often lacking in the profession [1].

2.1 Strategies to increase the percentage of women in engineering

Various pre-college strategies, such as engineering mentoring, internships, workshops, and career field trips, have been applied in an attempt to increase the percentage of women in engineering [9]. Activities like this provide young women with role models, promoting an 'if they can do it, then so can I' attitude. Another strategy to attract more women to engineering is to emphasize subjects in engineering that align with these students' values [13]. For example, emphasizing the connection between engineering and society was shown to appeal to a group of women engineers in New Zealand [14].

2.2 Sustainability as a subject that can help attract women to engineering

Sustainability seeks to optimize environmental, economic, and social considerations for current and future generations [15]. Sustainable engineering requires problem solving abilities to balance these considerations: for example, reducing energy consumption and emissions (environmental) while reducing cost (economic) and creating local jobs (social). Various organizations call for engineering educators to help their students achieve proficiency in sustainable engineering [16–18].

Sustainability may also be a subject that can help attract more women to engineering. Generally, women are catalysts for sustainable development [19]. Sheila Widnall, the first woman Secretary of the Air Force and now an engineering professor notes that 'Women are committed to the important values of our times, such as protecting the environment, product safety, and education . . . They are going to be a huge force in the solution of human problems.' The lack of a perceived connection between engineering and these societal problems is a top barrier to women entering the

field [20]. The subject of sustainability addresses this barrier, explicitly connecting engineers' contributions to problems such as energy and water resource depletion, climate change, and social inequity.

Some evidence supports a correlation between the subject of sustainability and increased percentages of women in engineering. At the University of Colorado at Boulder, the leadership board of the Engineers without Borders Program, which emphasizes the social aspect of sustainability, averaged over 50% women for a 5 year period. This percentage was much higher than the percentage of women on the leadership boards for other engineering groups at the University, including the American Society of Civil Engineers and American Society of Mechanical Engineers [3]. Similar increases in participation of underrepresented populations, including women, have been identified in the sustainability-themed engineering groups at Georgia Tech and Carnegie Mellon [2].

2.3 How this research expands the current body of knowledge

The current body of knowledge, in particular the preliminary findings from Colorado, Georgia Tech, and Carnegie Mellon inform and frame this research. To add to the current body of knowledge, this research is designed to examine a broad sample of academia and industry, with a specific focus on women in sustainable engineering *leadership* positions. Women in leadership positions serve as role models to help attract other women to engineering positions [21, 22]. While role models are important to engineers in general, women are much more likely than men to choose engineering through the influence of a role model [7].

3. RESEARCH METHODOLOGY

The objective of this research involved comparing the percentage of women in selected sustainable engineering leadership positions with the percentage of women in comparable general engineering positions. The subject industry leadership population for this study was 'sustainability leaders' at top design and construction companies. The subject academic leadership population was engineering faculty members attending workshops to share best practices for teaching sustainability.

3.1 Survey of industry leaders

The top 100 design firms and top 100 construction companies in the U.S., measured by revenue [23], were surveyed to identify the individual leading sustainability efforts at that company. This individual, whose title varied depending on the company, was defined as the one with the most authority in matters related to sustainability.

1. A review of the organizations' websites found that 13 of the top 100 design firms and 6 of the

construction companies listed the name of their sustainability leader on their website. Depending on the company, this individual had various titles such as: 'Leader of Sustainable Solutions', 'Sustainability Program Manager', 'Firm-wide Sustainable Design Leader', and 'Sustainable Design Coordinator.'

2. The remaining companies were contacted via their general contact e-mail. Thirty-one design firms and 27 construction companies responded. Most respondents provided the name of a sustainability leader, but several responded that there was no such individual at their company. Two weeks after the initial e-mail, a reminder e-mail was sent to unresponsive organizations. An additional 12 design firms and 6 construction companies responded to this second request.
3. Remaining non-respondents were contacted by phone using either the general information or main headquarters phone number. These calls generated responses from 13 design firms, 3 of which named a sustainability leader and 10 of which stated that there was no such position at the company. Of the 15 construction companies contacted via phone, 3 named a sustainability leader.

The overall response rate was 68 out of 100 design firms and 55 out of 100 construction companies. In each group, 22 respondents said they had no sustainability leader. In total, 79 sustainability leaders were identified: 46 from design firms and 33 from construction companies.

3.2 Survey of academic leaders

To complement the survey of industry leaders, data on academic sustainable engineering leaders were collected based on attendance at the national Center for Sustainable Engineering (CSE) workshops to share best practices for teaching sustainable engineering. Regardless of age, rank or experience, these faculty are leaders for student engineers. Established in 2005 through a collaboration between Carnegie Mellon, the University of Texas at Austin, and Arizona State University, the CSE is funded by the National Science Foundation and the Environmental Protection Agency [24]. To support their emphasis on improving sustainable engineering education in colleges and universities, CSE holds these two-day workshops for U.S. engineering faculty who either teach or plan to teach sustainable engineering. Attendance data were collected from all three workshops (2006, 2007, and 2009) held by CSE to date.

3.3 Statistical analysis

A pooled, two-proportion z-test is appropriate for comparing the percentage of women in the sustainable engineering leadership positions with the percentage of women in general engineering leadership positions. This procedure determines if percentages from two groups significantly differ from each other [25].

Specific applications of this pooled, two-proportion z-test, to this research are shown in Table 1 and Table 2. The general process for this test is as follows:

- Determine the pooled sample proportion as shown in Equation (1).
(1): $p = (p1 * n1 + p2 * n2) / (n1 + n2)$; where $p1$ is the sample proportion from population 1, $p2$ is the sample proportion from population 2, $n1$ is the size of sample 1, and $n2$ is the size of sample 2.
- Determine the standard error (SE) of the sampling distribution difference between the two proportions as shown in Equation (2).
(2): $SE = \sqrt{p * (1 - p) * [(1/n1) + (1/n2)]}$
- Determine the test statistic z-score (z) as shown in Equation (3).
(3): $z = (p1 - p2) / SE$
- Determine the P-value, which represents the probability of observing a sample statistic as extreme as the test statistic, as shown in Equation (4).
(4): $P = (1 - \text{table value}) * 2$; where the 'table value' is found using the test statistic z-score with the standard normal distribution table.
- Determine the confidence interval (CI) associated with the significance of the difference between the percentages from the two groups being compared, as shown in Equation (5).
(5): $CI = (1 - P) * 100$

4. RESULTS AND ANALYSIS

For the industry and academic populations studied, the percentage of women in sustainability leadership positions was much higher than the percentage in similar general leadership positions.

4.1 Results of the industry leaders survey

Thirty-eight percent of the industry sustainability leaders identified were women; including 16 of 46 (35%) in the design firms, and 14 of 33 (42%) in the construction companies. As shown in Fig. 1, this represents a much higher percentage of women than in any other position in the design and construction industry. In fact, no other position type in the design and construction industry has even half the percentage of women who occupy the sustainability leader positions. 2007 statistics from the U.S. Department of Labor show that, of the over 11.5 million people employed by the construction industry, only 9% are women. At 8%, the percentage of women in leadership 'construction manager' positions is even lower. In architectural and engineering professions, the overall percentage of women is only slightly higher (14%) with women comprising just 12% of those employed as civil engineers. As with the construction managers, the percentage of women in leadership 'engineering manager' positions is just 8% [26].

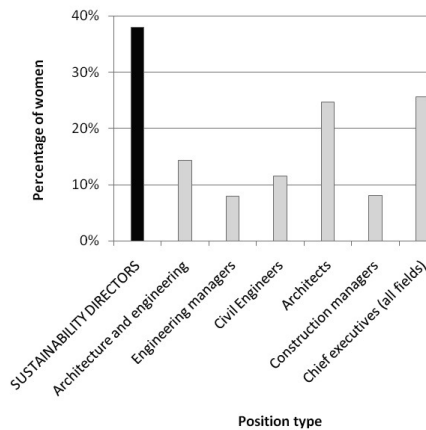


Fig. 1. Percentage of women in various industry positions.

Based on the pooled, two-proportion z-test, these results are statistically significant at a 99% confidence interval (Table 1). One might question whether the high percentage of women sustainability leaders is a result of these positions being filled from outside the design and construction industry. However, the percentage of women sustainability leaders is still significantly higher (at a 95% confidence interval) than the percentage of women in chief executive positions in all industries, not limited to design and construction.

Further analysis of the industry data shows that the percentage of women sustainability leaders was highest among the top 15 design firms and construction companies. A woman held the sustainability leader position for 11 of the 15 (73%) respondents from these 30 organizations. One possible explanation for this finding is that these larger organizations are able to hire specifically for the sustainability leader position, while smaller organizations are more apt to shift an employee from another position to fill the sustainability leader role. With a new hire or dedicated position, an organization has greater opportunity to align the skills and interests of the employee with the position, which may help explain the higher percentages in these larger organizations.

Table 1. Summary of the industry leaders' statistical analysis

	Sample size (n)	Proportion of women	<i>p</i>	<i>SE</i>	<i>z</i>	P-value	Significance
Sustainability leaders	79	0.380					
Other industry positions							
Architecture and engineering	2 932 000	0.144	0.14	0.04	5.97	< 0.0001	Yes (at 99%)
Engineering managers	114 000	0.080	0.08	0.03	9.81	< 0.0001	Yes (at 99%)
Civil Engineers	382 000	0.115	0.12	0.04	7.37	< 0.0001	Yes (at 99%)
Architects	240 000	0.247	0.25	0.05	2.74	0.006	Yes (at 99%)
Construction managers	1 176 000	0.081	0.08	0.03	9.73	< 0.0001	Yes (at 99%)
Leadership position							
Chief executives (all fields)	1 649 000	0.256	0.26	0.05	2.52	0.012	Yes (at 95%)

p = pooled sample proportion: see Equation (1)

SE = standard error: see Equation (2)

z = test statistic: see Equation (3)

P-value: see Equation (4)

Significance: see Equation (5)

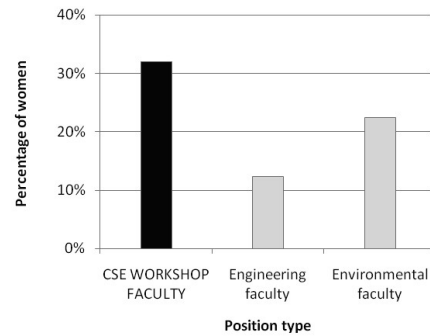


Fig. 2. Percentage of women in selected engineering faculty roles

4.2 Results of the academic leaders survey

Similar to the findings from industry, the percentage of women attending the CSE workshops was much higher than the percentage of women engineering faculty in general: 32% of the over 180 participants in CSE workshops to date have been women, with percentages increasing each year. In comparison, the most recent data shows that just 12% of all engineering faculty are women (Fig. 2) [8].

Based on the pooled, two-proportion z-test, these results are statistically significant at a 99% confidence interval (Table 2). Even the percentage of women faculty in the discipline with the highest percentage of women, environmental engineering (22%), is much lower (at a 95% confidence interval) than the percentage of women attending CSE workshops.

5. DISCUSSION

The results of this research suggest that women are more likely to pursue engineering and related fields when the subject of sustainability is emphasized. Therefore, *incorporation of sustainability in engineering, a key need in itself* [16, 17], *is likely to have ancillary benefits by addressing the need to attract more women to the field.*

Table 2. Summary of the academic leaders' statistical analysis

	Sample size	Proportion of women	<i>p</i>	<i>SE</i>	<i>z</i>	P-value	Significance
CSE workshop faculty	180	0.320					
Engineering faculty	24 207	0.123	0.12	0.02	7.98	< 0.0001	Yes (at 99%)
Environmental faculty	196	0.223	0.27	0.05	2.09	0.04	Yes (at 95%)

p = pooled sample proportion: see Equation (1)
SE = standard error: see Equation (2)
z = test statistic: see Equation (3)
 P-value = using *z* table: see Equation (4)
 Significance: see Equation (5)

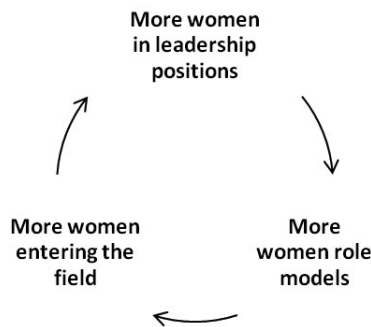


Fig. 3. The 'women as sustainability leaders' positive feedback loop

5.1 The 'women as sustainability leaders' positive feedback loop

For leadership populations, like those studied here, the implications of the correlation between sustainability and participation of women in engineering are especially pronounced. Women in leadership positions serve as role models to attract other women to the field [21, 22]. Accordingly, the increased percentage of women in sustainability leadership positions is expected to attract more women to the field, which will lead to a greater percentage of women in leadership positions, and so on. Fig. 3 shows this 'positive feedback loop', in which an increase in one area causes an increase in another area, which in turn causes an increase in the first area [28]. A survey respondent explained her firsthand experience with this feedback loop, noting that: 'it is also easier (I've found) to find female mentors/leaders in . . . sustainability than . . . in civil engineering and in the military.'

5.2 Recommendations

Combined with the existing body of knowledge, the findings from this study produce recommendations for applying the subject of sustainability to increase the percentage of women in engineering.

1. *Integrate sustainability in engineering education and practice* Despite recommendations from leading organizations [16, 17] and increasing numbers of individual courses that emphasize sustainability, the vast majority of engineering programs have yet to infuse sustainability across the curriculum [29]. Engineering programs like James Madison University's, which

make sustainability an overarching theme, are the exception rather than the rule [30]. In industry, over one third (44 of 123) of the organizations responding to the survey did not have anyone responsible for organization-wide sustainability. Improved integration of sustainability in engineering education and practice will not only yield better engineering solutions, it is also likely to help attract a higher percentage of women to the field.

2. *Publicize sustainability leadership opportunities for engineers* Leadership from engineers is critical in the pursuit of sustainability. Publicizing this requirement, beginning with young women, could help attract and retain more women in the engineering disciplines.

6. FUTURE RESEARCH

Both data sets analyzed in this research show a positive, statistically significant, correlation between the subject of sustainability and the percentage of women in engineering leadership positions. Still, the question remains: 'Is sustainability a causal factor for the higher percentage of women in sustainable engineering leadership positions?'

To help guide future research into this question, a qualitative follow-up survey was conducted among the women identified in the initial data sets. Twenty-seven women (14 from industry and 13 academics) responded to this series of questions designed to begin investigating causality between the percentage of women and the subject of sustainability.

6.1 Potential alternative explanations for the correlation

Alternative explanations would discredit a causal link between the subject of sustainability and the percentage of women in leadership positions. Some of these alternative explanations are provided here along with discussions, supported by responses to the qualitative survey, indicating that each of the alternative explanations may not be an explanatory variable. Still, additional research into these alternative explanations is needed to increase understanding of the connection between the

Table 3. Expanded responses to factors contributing to the higher percentage of women

Category	Number of Instances		
	Industry	Academia	Total
Sustainability requires strengths inherent in women	6	7	13
Sustainability happens to align with characteristics of women	6	5	11
Sustainability provides an opportunity to painlessly satisfy diversity goals	3	–	3

subject of sustainability and women in engineering leadership positions.

One alternative explanation for the correlation between sustainability and women in engineering leadership positions is that organizations employing a sustainability leader are typically forward-thinking, and are therefore more likely to have a higher percentage of women in leadership positions. However, the results from the qualitative survey do not support this explanation. Respondents estimated the percentage of women in leadership positions in their companies (15%) and departments (21%) as close to the industry average and significantly below the percentage of sustainability leaders.

A second alternative explanation for the correlation is that women represent a higher percentage of younger engineers and are therefore more likely to possess formal education in relatively new subjects like sustainability. However, the available data also fails to support this explanation. First, the percentage of women among newly graduated engineers is still well below the percentages in sustainability leadership positions [8]. Second, more than half of the qualitative survey respondents received their latest degree prior to 2000. Finally, the qualitative survey respondents who attended the CSE workshops received their doctorate degree an average of 13 years ago, with the most recent Ph.D. received in 2002.

A third alternative explanation for the correlation is that sustainability leadership positions do not require a 'technical' background, so more women are eligible for these positions. However, qualitative survey results showed that all but three of the women hold degrees in science, technology, engineering or math, with the remaining three respondents holding degrees in architecture. Many of the women had a combination of degrees to broaden their abilities, such as a BS in Civil Engineering and an MBA. Survey respondents' most recent degrees earned included engineering (5), architecture (3), environmental studies (3), construction management (2), and administration (2).

6.2 Expert opinions on causality

To help guide future research, the sustainability leader respondents to the qualitative survey were asked explicitly if they thought the subject of sustainability was an explanatory factor for the higher percentage of women in leadership positions. Four respondents thought that sustainability was *the* key factor; 19 thought that the subject of

sustainability was one of many factors; and three thought the subject of sustainability was not a factor.

Respondents were prompted to expand upon these answers with one or more explanations. As shown in Table 3, these expanded answers fell roughly into three general categories. While limited in scope, these responses are included here to help guide future research questions.

Thirteen of the 27 responses suggest that *sustainability requires strengths inherent in women*. These responses support the notion of sustainability as a subject that appeals to the interests and talents of women. For example, women are more likely to practice interactive leadership [27], which is especially useful in new and evolving fields like sustainability. Selected responses from this category include:

Women tend to be caretakers, and sustainability is the largest application of this sensibility that there is (3 similar instances).

Holistic and strategic thinking and risk management skills (are) attributes of women (3 similar instances).

Sustainability shows how the field of engineering can have a positive impact on the lives of many people (2 similar instances).

Many women want a career where they are working for more than just a paycheck. Sustainability often feels more like a calling 'than just a job' (2 similar instances).

The young field of sustainability requires a balance between technical know-how and relationship building as well, and I think that striking such a balance is often a female strength.

At the heart of sustainability is nurturing the earth, which may be more inherent in women.

11 of the 27 expanded responses suggest that sustainability happens to align with characteristics of women.

These responses support a relationship between the subject of sustainability and greater percentages of women in leadership positions. However, these responses also imply that the relationship is for reasons other than interest and talent in the subject of sustainability. For example:

A higher percentage of women are already in environmental sciences and engineering; sustainability is a natural extension of that (2 similar instances).

Women are less likely to accept the corporate status quo as it has not worked for them. There is no risk in

going out on a limb for a subject that you are passionate about.

There is an alignment of sustainability with other positions traditionally held by women (Human Resources, Community Service and Marketing).

Sustainability is a new, growing field—women are excited about new opportunities.

It is also easier . . . to find female mentors/leaders in environmental engineering and sustainability than I encountered in civil engineering and in the military.

Women are not as ‘scared’ as men to look like ‘tree huggers’ or ‘bleeding hearts’ . . . our ego is not vulnerable within the industry/peer-group to such silly fears.

It is my impression that women appreciate a career field where they feel they are positively contributing to the health of their community and planet.

This is a growth area that was at least initially not seen as competitive or desirable. In a field with relatively limited leadership opportunities for women, perhaps women foresaw a growth opportunity in this particular niche. Had the role been seen as being as critical to success as it now is, I suspect the competition for the role would have been more intense across the board and we would have seen a similar percentage of women in these roles as elsewhere in the profession. As it was, you had to be willing to take a big risk to associate yourself entirely with a subject that as recently as 10 years ago was seen as on the fringe.

Perhaps the research fields related to sustainability attract proportionally more women than other fields, and therefore more women teach in these areas

More women are entering academia. If newer generation includes more women, a new subject like sustainability would be reflected in this population.

Finally, 3 of the 27 expanded responses suggest that sustainability provides an opportunity for companies to painlessly satisfy diversity goals. The thought behind this philosophy is that sustainability leadership positions are viewed as less important than others and therefore an easy place to get credit for having women in leadership positions.

(sustainability) probably is considered by company leaders as the softer (side) of the industry (2 similar instances).

Most companies are interested in promoting women for diversification. This is an area in which younger women can be promoted without conflict with others who have been with the company much longer.

7. CONCLUSIONS

Several limitations warrant consideration when interpreting the conclusions based on this research. First, the data sets for this research are not a perfect cross-section of all engineers in sustainability leadership positions. The industry data are from the design and construction industry in which engineers are predominantly from the Civil, Mechanical, and Electrical disciplines, and where some leaders have non-engineering backgrounds. The academic data represent a broad spectrum of engineering disciplines, but excludes any faculty members teaching sustainable engineering who have not attended CSE workshops.

Despite these limitations, this research does provide empirical evidence that the participation of women in selected sustainable engineering leadership positions is significantly greater than their participation in similar leadership positions. This finding supports the connection between the subject of sustainability and greater participation of women in engineering. Incorporating the subject of sustainability in engineering, a crucial need in itself, seems to also address the crucial need to increase the percentage of women in the field. This research identified a positive correlation between the subject of sustainability and the percentages of women in engineering leadership positions in industry and academia. Women in these leadership positions in industry and academia serve as role models to other women, helping them aspire to similar leadership positions.

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Jennilee Harrison is a graduate student in the Department of Civil Engineering at Clemson University. Her expected graduation is May 2010. Her future goals are to obtain a leadership position in sustainability, educate and excite people about sustainable design and construction, and travel the world and experience new places.

Leidy Klotz leads the Engineering Sustainable Solutions research group in the Department of Civil Engineering at Clemson University. The group does research to support engineering solutions that maximize social, economic, and environmental benefits for current and future humans. This research ranges from management practices to teaching strategies for sustainable engineering.