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The Sustainability Decisions of First-Year Engineering Students

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1. ABSTRACT

Sustainable engineering emphasizes energy efficiency and resource conservation in an effort to secure a habitable environment for current and future generations. Hence, sustainability is an important topic in engineering education. The objective of this study was to examine the importance first-year engineering students place on the economic, social, and environmental aspects of sustainability, and how they apply those views to their engineering design decisions. In 28 teams of three or four, the engineering students were prompted to choose one of the three energy reduction strategies—solar panel array, green roof, and make no change—for a local library, and explain their decision in a short memo. Document analysis of the memos revealed that 15 teams chose solar panels, five teams chose no change, six teams chose green roof, and two teams chose to employ a hybrid of the solar panels and green roof. While data given to the students indicated that each of the individual solutions had a distinct advantage over the other solutions in one aspect of sustainability—economic, social, and environmental—most teams indicated a combination of these reasons for their decisions. Overall, approximately 93% of the teams identified economic reasons, 75% identified environmental reasons, and only 18% identified social reasons. Since very few teams kept their focus on societal aspects, we recommend that instructors should give additional attention to the social aspect of sustainability engineering to give students a more complete view of sustainable design.

2. INTRODUCTION

Sustainability is an important aspect of engineering which focuses on long lasting improvements of the environment, society, and also emphasizes minimizing costs and consequences of engineering projects. As Azapagic, Perdan, & Shallcross (2005) and Kagawa (2007) suggested, while sustainable thinking is essential for the long term success of engineering projects, and thus a valued topic in engineering education, prior research suggests that students have only slight or intermediate knowledge of sustainability and related concepts. In order to aid educators who strive to enhance students' understanding of sustainability, more must be known about how students apply knowledge of sustainability in design contexts. The purpose of this study is to observe how first-year engineering students approach design decisions based on their view of sustainability. In this study, we rely upon the framework described by Munasinghe (1993).

Sustainability comprises three main areas: economic sustainability, environmental sustainability, and societal sustainability. In our study we assigned first year engineering students a design task which highlighted each of the three main focuses of sustainability. The students were prompted to make a sustainable decision based on the information presented to them and explain why they made that decision.

3. LITERATURE REVIEW

In this study, we identified on three main aspects of sustainability; economic, environmental, and social, based on Munasinghe's (1993) sustainability triangle. Those focused on economic sustainability aim to maximize economic gains by increasing income and decreasing costs. Companies who hire engineers aim to make a profit on their products and services, therefore engineers must have an understanding of the economic sustainability of their design decisions in order to develop projects that represent valuable long-term investments. Environmental sustainability focuses on conservation of scarce resources and the environment. As the supply of these resources is shrinking, nonrenewable resources are very important to today's society. Engineers must be able to make design decisions which take this into consideration and actively conserve these resources. Societal sustainability aims to help and improve the local society and cultural systems. It is important for engineers to understand societal sustainability because projects in process have the potential to affect communities.

Azapagic, *et al.* (2005) and Kagawa (2007) explained while most engineering students have some understanding of sustainability most overlook the social and economic aspects of sustainability. Kagawa (2007) expanded when asked to write 4 keywords which they felt described sustainability, 46% of the keywords collected from the engineering students in the study related to environmental sustainability while only 3% of the keywords related to social sustainability and 4% related to economic sustainability. From this information we gain a better understanding of how engineering students view sustainability. Many engineering students correlate the idea of sustainability with the environment but not many of them think about the other considerations that should be accounted for when making sustainable design decisions. In order for students to become successful engineers, the engineering education curriculum has to improve the problems relating with sustainability. It's our job to educate them in all contexts of sustainability. As Azapagic (2005) and colleagues assert, "sustainability must become part of their [engineering students'] everyday thinking." The engineering educators must strive to incorporate sustainability into student projects and assignments. Students in the early stages of engineering who will be trained to think in a sustainable way will have more opportunities for success in their engineering careers.

4. METHODS

4.1 Setting

This study was conducted within the context of a first-year engineering course at Purdue University during the Fall 2011 semester. In this introductory class, students learn about engineering disciplines, teamwork, computer tools, and the engineering design process through team projects/activities, interactive lectures, and individual assignments.

4.2 Participants

The participants in this study were students in a first-year engineering course at Purdue University. The students comprised twenty-eight teams of three to four, in which students had worked both in and out of class for about two months.

4.3 Data Collection

The teams were introduced to sustainability in engineering design and presented with descriptions of the three corners of Munasinghe's (1993) sustainability triangle during a regular class meeting. They were presented with information about the energy needs of a local library, which relied on electrical energy provided by a regional energy supplier, and two alternative energy options (solar panels and green roofs). The teams were given fifteen minutes to analyze the library's predicted energy requirements, energy costs, total system costs, and CO_2 emissions over a period of 10 years for each energy option (Table 1) and to advise the library to make no changes to their current energy system, to supplement electricity usage with a solar panel array on the roof, or to reduce heating and cooling needs by installing a green roof. Each of the three options was strongly linked to one of the corners of Munasinghe's (1993) sustainability triangle. *No Change* represented the lowest cost, and thus economical, option. *Solar Panels* represented the least carbon dioxide emissions, and thus most environmentally conscious option. *Green Roof* is an additional area of peace and beauty that could be enjoyed by the public, and thus represented the best societal option. Each of the twenty-eight teams responded with a hand-written memo outlining their recommendation and reasoning behind it.

Table 1: Information given to students on the three energy alternatives

For 10-year period	**No Change**	**Solar Panel**	**Green Roof**
Energy needed	8,000,000 kWh	7,500,000 kWh	7,800,000 kWh
Energy cost	$800,000	$750,000	$780,000
Total cost	$800,000	$1,200,000	$1,200,000
CO_2 Emissions	No change	-400,000 kg	-250,000 kg

4.4 Data Analysis

Each team's submission was analyzed based on recommendation and rationale. During the initial phase of analysis we coded each team's memo for official recommendation (e.g. no change or install a solar panel array) and the unique reasons they gave in support of that recommendation (e.g. reduced CO_2 emissions or energy cost). Teams recommended either no change, install solar panels, install a green roof, or a hybrid decision of both the solar panels and green roof. During a second phase of analysis, we identified the most applicable of the three focuses of sustainable development (economical, societal, and environmental) for each unique reason. Table 2 demonstrates examples of this analysis. We performed frequency counts for each of the solution types and focus of sustainable development. We further performed frequency counts for each focus of sustainable development given one of the four solution types. Since some of the teams gave multiple reasons for their decision, the number of counts for the three foci of sustainable development exceeds the number of teams.

Table 2: Examples of Reasons Linked to Decision-Focus Pairs

Decision	**Focus**	**Example Reason**
No Change	Economical	This option has the cheapest total cost.
	Societal	N/A
	Environmental	N/A
Green Roof	Economical	Cuts Energy Costs
	Societal	Aesthetic Appeal
	Environmental	Cuts CO2 Emissions
Solar Panels	Economical	The cost will be paid off over time
	Societal	N/A
	Environmental	This option has the lowest CO2 Emissions/is the most eco friendly
Hybrid	Economical	Solar Panels save most in energy costs
	Societal	Green roof will provide community opportunities
	Environmental	Solar Panels and green roof will lower CO2 Emissions

5. RESULTS

The results show that 7% of the first-year engineering students chose hybrid as their sustainable decision, 18% chose no change, 21% chose green roof, and 54% chose to install arrays of solar panels. These proportions can be viewed in Figure 1. The results indicate that the most popular choice was to install the solar panel array.

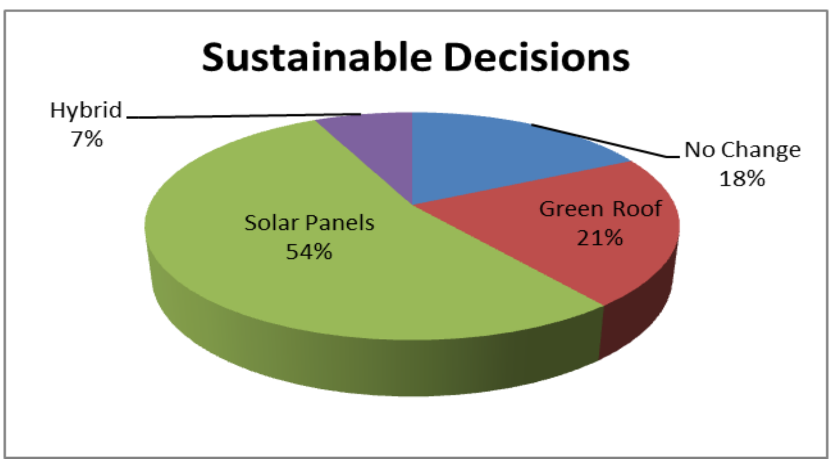

Figure 1: Proportion of decisions chosen by each team.

Table 3 shows the total number of teams who presented economic, societal, and/or environmental reasons for their recommendation. The results are divided by solution choice and given in aggregate form.

Table 3: Twenty-eight Teams Responses Involving their Focus

Decision	**Economic Reason**	**Societal Reason**	**Environmental Reason**
No Change	5	0	0
Green Roof	5	4	5
Solar Panels	14	0	14
Hybrid*	2	1	2
Total	26	5	21
Percent	92.9%	17.9%	75.0%

*Hybrid decision is choosing both the green roof and the solar panels

6. DISCUSSION

6.1 Most Popular Decision: Solar Panels

Of the three given choices shown in Table1, most teams (15) chose to install the solar panel array. Among these fifteen teams, all but one team chose solar panels at least in part because they were the most environmentally favorable (due to the lowest CO_2 emissions). Similarly, fourteen teams listed economics in their rationale. Multiple teams suggested that the additional $400,000 compared to *no change* was worth the investment as long as it helps the environment. Seven teams mentioned that the cost was similar to the green roof option in order to install solar panel array. Six teams who chose solar panels on the basis of cost made a mathematical error, suggesting that the energy savings would cause the library to break even for the installation cost after eight years. Though, based on the given data, solar panels would eventually overtake *no change* as the least expensive option after 80 years, this error did cause teams to overestimate the economic benefit of the solar panels, and thus may have erroneously influenced their recommendation.

6.2 Second Most Popular Decision: Green Roof

Out of the twenty-eight teams, six teams chose to reduce heating and cooling needs by installing a green roof. Out of these six teams, four teams highlighted the aesthetic appeal of the garden, citing the positive effect the green roof would have on library patrons and the community as a whole. Surprisingly, greater numbers of teams indicated economics and environment reasons for their decisions. Though the data given indicate that solar panels reduce carbon dioxide emissions at a greater rate than green roofs, students still saw green roofs as the "most environmentally-efficient option." This misconception is likely due to the inclusion of "green" in the title and the images of trees and plants presented in example photographs. The teams that identified economic reasons pointed out lower energy costs and lower maintenance costs (not explicitly stated to students) than *no change* and *solar panels* respectively.

6.3 Least Popular Decision: No Change

Out of the twenty-eight teams of first year engineering students, five teams chose to make no change to the current system (electrical power). The teams chose to make no change by focusing on the long-term cost. Out of the five teams, three teams reasoned that the library will not save enough energy/cost in the long run by choosing the other two options. Three teams made the assumption that the technology will change drastically over time before the other two options start playing their economical and environmental friendly roles. No teams identified either environmental or societal reasons for selected *no change*, which was expected.

6.4 Hybrid decision

Out of the twenty-eight teams of first year engineering students, two teams chose to implement both the green roof and the solar panel array option hence the hybrid decision. This was not an option provided to the students however; the results show that these two teams also made their decision regarding helping the environment even at a high cost.

7. CONCLUSION

Overall, the purpose of this research was achieved. The assignment provided to the first-year engineering students helped us observe how these students view sustainability and what changes need to be made in the curriculum in terms of societal sustainability. The 28 teams from this first-year engineering class demonstrated concern for the economic sustainability of their decisions. Table 3 shows that 92.9% of the teams used reasoning which held an economic focus. We found that 82.14% of the teams chose to install the solar panel array, green roof, or a hybrid of the two. From these results we can conclude that the first-year engineering students have a high focus on environmental sustainability and economical sustainability. Since 17.9% used reasoning that took the societal effects of their decision into consideration, these conclusions can be used in a classroom setting by emphasizing the importance of societal sustainability. Further research with a wider population of first-year engineering students needs to be done in order for these results to be applied throughout the nation.

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