# PSTAT: Promoting Sustainable Transportation Among Teens

Final Report to the US Environmental Protection Agency*

Faculty Advisors:

Dr. Paul Frymier (PI), Chemical and Biomolecular Engineering; Dr. Chris Cherry, Civil and Environmental Engineering; Dr. David Irick, Mechanical, Aerospace, and Biomedical Engineering; Dr. Leon Tolbert, Electrical Engineering

Student Authors:

Jordan Bryner, Chemical and Biomolecular Engineering**;** Yi Ying Chin, Chemical and Biomolecular Engineering**;** Jeffrey Clark, Chemical and Biomolecular Engineering**;** Candice Patton, Electrical Engineering**;** Rebekah Patton, Chemical and Biomolecular Engineering**;** Christopher Stanfill, Mechanical Engineering**;** Rick Wheeler, Civil and Environmental Engineering

*Note: This version of the report has been edited so that it can be made publically available. To request a copy of the original report, contact Dr. Paul Frymier at pdf@utk.edu

# Table of Contents

Project Report Executive Summary ..... I
A. Summary of Phase I Results ..... 1
1. Background and Problem Definition ..... 1
2. Purpose, Objective, Scope ..... 3
3. Data, Findings, Outputs/Outcomes ..... 4
4. Discussion, Conclusions, and Recommendations ..... 6
B. Proposal for Phase II ..... 10
1. P3 Phase II Project Description ..... 10
Overall Actual and Potential Sustainability Benefits of the Proposed Project ..... 10
General Relationship of Challenge to Sustainability ..... 11
Challenge Definition and Relationship to Phase I ..... 12
Innovation and Technical Merit ..... 12
Results, Evaluation and Demonstration ..... 13
Integration of P3 Concepts as an Educational Tool ..... 13
Interdisciplinary Teamwork ..... 14
2. Project Schedule ..... 15
C. References ..... 16
Budget and Budget Justification ..... 17
Appendix ..... i

## Project Report Executive Summary

**Date of Project Report:** March 18, 2013
**Project Title:** PSTAT: Promoting Sustainable Transportation Among Teens
**Principal Investigator:** Dr. Paul Frymier, Chemical and Biomolecular Engineering
**Co-Investigators:** Dr. Chris Cherry, Civil and Environmental Engineering
Dr. David Irick, Mechanical, Aerospace, and Biomedical Engineering
Dr. Leon Tolbert, Electrical Engineering
**Student Team:** Jordan Bryner, Chemical and Biomolecular Engineering
Yi Ying Chin, Chemical and Biomolecular Engineering
Jeffrey Clark, Chemical and Biomolecular Engineering
Candice Patton, Electrical Engineering
Rebekah Patton, Chemical and Biomolecular Engineering
Christopher Stanfill, Mechanical Engineering
Rick Wheeler, Civil and Environmental Engineering
**Institution:** University of Tennessee, Knoxville
**Project Period:** 9/15/2012 – 9/14/2013
**Description and Objective of Research:**

Can an innovative, team-based, hands-on design and construction project involving high school students change their attitudes and personal preferences for transportation to favour lower impact modes? This was the main question PSTAT (Promoting Sustainable Transportation Among Teens) was designed to answer. Since the last decade, global climate change has fuelled increased development of alternative transportation modes that have lesser impact on the environment in terms of greenhouse gas (GHG) emissions. However, society is not embracing the change with open arms; sales of alternative fuel and electric vehicles are a small fraction of the total vehicle fleet. Therefore, there is a critical need for a paradigm shift, which could be especially timely for teen-aged students starting to adopt their own personal transportation preferences. By exposing high school students to a hands-on activity that introduced them to alternative transportation, it was hoped to provide a partially social solution to what is currently viewed as a primarily technical problem – the overwhelming dependence of the United States' personal transportation system on petroleum. PSTAT involved three teams of high school students in Knoxville, TN, where each had University of Tennessee, Knoxville (UTK) undergraduate engineering students as mentors. The student teams were to design and construct an electrically assisted bicycle, commonly known as an e-bike, that fulfilled the criteria set for a competition of the e-bikes' performance at the end of the project on UTK campus. A sustainability analysis detailing the environmental, human health and economic impacts of three different commuting scenarios was conducted by each high school as well. The sustainability analysis quantitatively displayed the impacts of various commuting choices, emphasizing the impacts of the current transportation situation in the United States and more importantly the benefits of lower impact transportation modes. Pre-and post-project surveys were conducted to measure the change in students' perception and likelihood of adopting lower impact transportation modes in the future.

**Summary of Findings (Outputs/Outcomes):**

The results of this project are primarily measured by differences in surveys given to students before and after PSTAT. Figures 1 and 2 present the data from two of the questions

showing the difference in opinions of the students' pre- and post-project. The question regarding Figure 1 asked students to rank attributes according to their priorities when choosing a mode of transportation and that of Figure 2 asked the students to rank the likely mode of transportation they will use to commute in the future. Points near the edge of the radar plot represent attributes/modes that are more significant to the individual. In Figure 1, the attributes of performance and style became less important while the attributes of environmental and human health impacts became more important after the project. Similarly, Figure 2 illustrates that the personal preference of the students shifted to favour bikes and battery electric vehicles (BEVs) after the project, when compared to their preferences before the project.

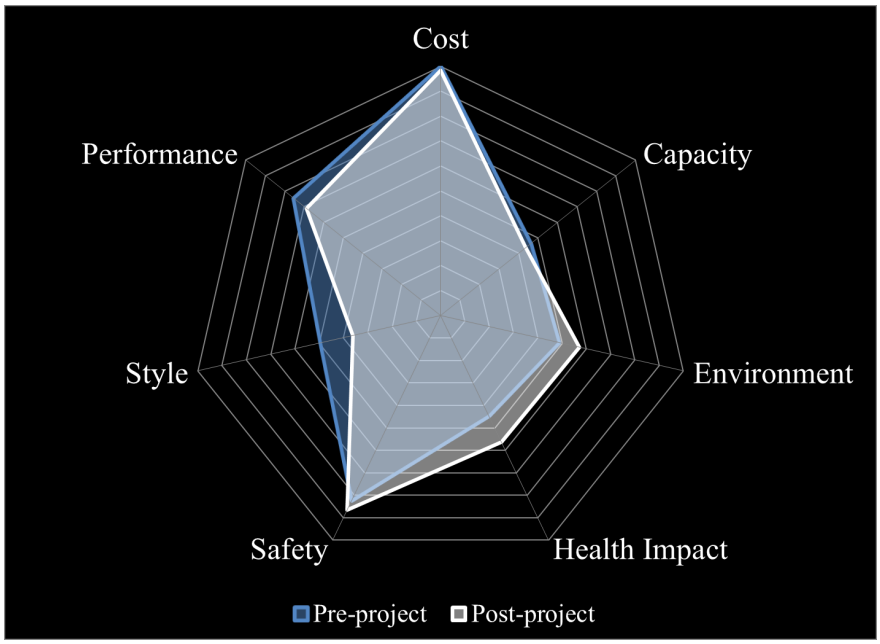


**Figure 1.** Survey results of attributes of future commuting choices.

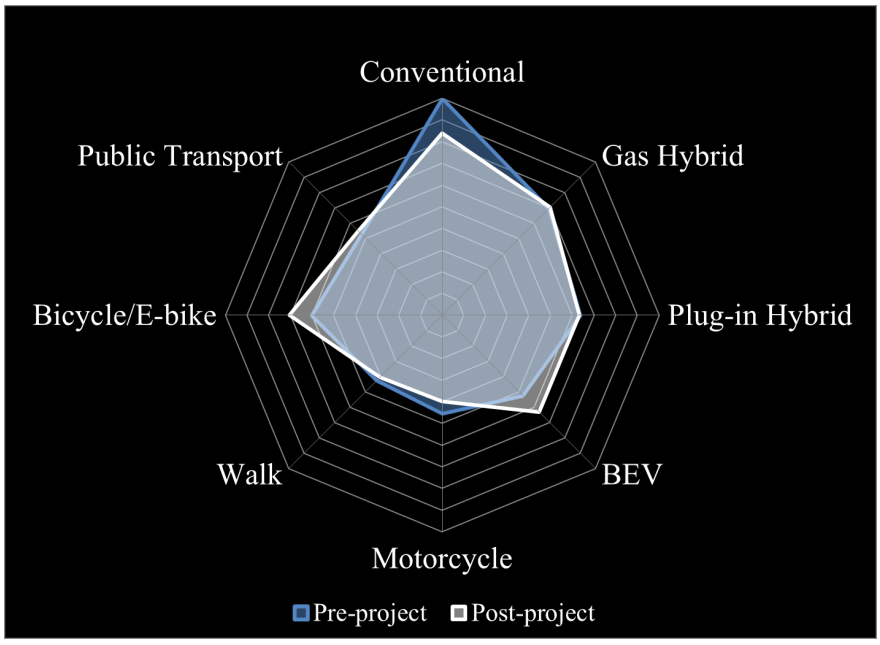


**Figure 2.** Survey results of the student preferences on future commuting methods.

**Conclusions:**

Promoting Sustainable Transportation Among Teens (PSTAT) has shown that such a project does result in a measurable change in the students' stated preferences and attitudes. This program influenced students to revaluate their transportation choices by simply exposing them to knowledge of lower impact modes of transportation and the results show that this project has been successful. As a pilot program, several areas for improvement were identified, but overall,

the program was judged to be highly beneficial, as judged by qualitative comments from the students' high school teachers, their parents, and the students themselves.

**Proposed Phase II Objectives and Strategies:**

Phase II of PSTAT maintains the same objective as Phase I, which is to spear-head a shift in students' priorities concerning transportation choices at a critical stage of their lives, but seeks to create a larger impact within the Knoxville and greater East Tennessee community. In order to achieve the goal, the first year of Phase II will double the reach of the project by expanding the project to six high schools in Knox County. About a month will be given to promote the program in participating high schools and recruit interested students, ensuring that the project reaches the whole school community. To improve the effectiveness of PSTAT, the UTK engineering student advisors will develop standardized packet with material covered by all the represented engineering disciplines (electrical, mechanical, civil, and chemical) to ensure all teams have sufficient and equal information for the project. These packets will be developed before the assignment of teams for the fall semester. The undergraduate advisors will meet with their student teams once a week to serve as resources to the teams in the design and construction process. A sustainability analysis will also be part of Phase II, but the analysis will be simplified and the student teams will be asked to begin developing the analyses as soon as the bikes are designed, ensuring a quality analysis. This will also give the students enough time to fully appreciate the conclusions of the analysis, which will increase the impact of the project. As with Phase I, each team will present a poster documenting the design and expected performance of each team's e-bike and their sustainability analysis. This will be done at a final competition which brings all the teams together that will be held in March on the University of Tennessee campus. As in Phase I, Parents, the local media, and the community at large will be invited to the event to increase the impact. Based on the Phase I competition participation, attendance at the event is expected to be high (most students had multiple family members present as well as friends not directly involved in the project and the event was covered by a local television station).

**Publications/Presentations:** No peer-reviewed publications to date. The University published a press release which resulted in television coverage of the final competition. In April, the project Phase I results will be presented at an annual Earth Day event in Oak Ridge, Tennessee.

**Supplemental Keywords:**
Global warming, greenhouse gas, sustainability analysis, e-bike

**Relevant Websites:** None.

## A. Summary of Phase I Results

### 1. Background and Problem Definition

The overall goal of the Phase I P3 project "Promoting Sustainable Transportation Among Teens" (PSTAT) was to introduce a new educational program to high schools in the Knoxville area focusing on resource efficient personal transportation methods. The students were given the opportunity to learn about low impact modes of transportation in an interactive and educational manner through both the construction of electric bicycles (e-bikes) and the completion of a scenario-based sustainability analysis. Mentors from the University Of Tennessee College Of Engineering prepared and presented lessons that investigated alternative transportation methods and provided the knowledge base for the design, construction, and analysis of e-bikes. The students were instructed to utilize knowledge obtained in their math and science courses to optimally design their e-bike for typical commuting scenarios. The project aimed to introduce alternative transportation methods in an exciting and engaging way, culminating in an e-bike competition hosted by students in the College of Engineering at the University of Tennessee.

It was desired that this unique educational opportunity provide a primarily social and educational solution to what is often thought of as a technical problem, namely the large dependence of the United States' personal transportation system on petroleum, a finite resource.[1] Nearly all personal vehicles in the United States operate using an internal combustion engine (ICE) powered by gasoline, a petroleum derivative.[2] Gasoline combustion for automotive use is one of the primary sources of carbon dioxide emissions into the atmosphere and, as such, has been linked to global climate change.[3] Along with carbon dioxide, other emissions are released as a result of the combustion including nitrogen oxides ($NO_x$), carbon monoxide (CO), and unburned hydrocarbons, all of which are harmful to human health.[4] An overall shift in the United States transportation system towards vehicles with fewer harmful tailpipe emissions is needed to effectively combat global climate change and minimize the potential harmful effects on overall human health. By allowing students to see the benefits of energy efficient transportation at a formative age and encouraging them to implement it throughout their lifetime, it is hoped that this paradigm shift will be stimulated. The social impact and effectiveness of the program were measured via pre- and post-project surveys taken by both the participants and mentors. The results of which are discussed later in this report.

The PSTAT project was designed to determine the effect of an engaging and educational project on the perception high school students have on low impact, potentially sustainable transportation. The project goal was achieved in three steps:

1) Give high school students a survey of their personal transportation preferences.
2) Have them participate in an engaging, novel, team-based project involving low impact personal transportation modes.
3) Give them an exit survey and document any changes in attitudes and preferences for their personal transportation choices.

Executing the project involved the following specific tasks:

- Create three teams of local high school students to build electric bicycles,
- Provide undergraduate student advisors from the College of Engineering to these high school students to assist in the design, construction, and analysis of these bicycles,

- Allow these students to display the results of their work throughout the school year via social media, bulletin boards, in-class teaching modules, a showcase in the University of Tennessee "Switch Your Thinking" program, and ultimately a competition between the three teams on the university campus.

Once the notification of funding was received, a socio-economically diverse group of Knox County schools were contacted to participate in the project. The necessary approvals were given from the school system and teams were created at Farragut High School, Fulton High School, and West High School. Each team was provided with two undergraduate advisors, a male and a female undergraduate student majoring in chemical engineering, civil and environmental engineering, electrical engineering, or mechanical engineering. General instructions and a budget of $2,100 were provided to the team, but the design specifics and budget allocation was left largely to the individual team's judgment.

Throughout the academic year, the teams worked to design and build their e-bike, taking into account the events that the e-bike would be required to complete in during the competition hosted on the University of Tennessee campus on February 10th, 2013. The judging for the competition included several scored events which measured e-bike performance and subsequently influenced the designs:

1) **Hill Climbing** The riders are timed climbing a steep grade without pedaling, bikes limited electrically to 20 mph.
2) **Simulated Commuting:** The riders are timed completing an obstacle course, bikes limited electrically to 20 mph.
3) **Pedal-Only** The riders are timed using only human power, no speed limit
4) **Fastest Bike:** The bike was timed on a short straight course, no speed limit.
5) **Quality of Construction:** Each entry was judged for the quality of the installation, including ease of charging, ease of repairing a flat tire, wires and all equipment properly secured, etc.
6) **Outreach to Social Media:** Points were awarded for the number of "Likes" for each team's Facebook page.

In addition to these six scored events, each team received a score for the presentation and defense of a poster for a team of UT faculty and graduate student judges and a written report with a sustainability analysis. The sustainability analysis was a key resource used by the undergraduate advisors to emphasize the benefit of environmentally-friendly transportation. Each analysis detailed and compared the impacts of three scenarios on human health, the environment, and the economy. The three scenarios were:

1) **Current Scenario**: The team developed a profile of the current commuting habits of their school, developed via a survey sampling of their classmates, etc. The profile included the percentage of students at the school who drive to work, ride with a friend or parent in a car, walk, ride a bike, take a bus, etc.
2) **E-bike Scenario**: 100% of student drivers switch to e-bikes for four days a week. The other day, they use whatever means of commuting they currently use (drive car, walk, ride bus, etc.). This simulates very rainy days, extreme cold, etc. when students are unlikely to ride a bike.

3) **Electric Cars**: All cars used by students at the school are switched to the Nissan Leaf. All other forms of commuting (walking, riding bike, etc.) remain the same.

The results of these scenarios were determined and presented in tabular form and a discussion of the results was included in the written report. An example is included in Table 1 in the Data, Findings, and Outcomes section later in this report.

**2. Purpose, Objective, Scope**

**Purpose:** The purpose of the PSTAT project was to enhance new teenage drivers' understanding of low impact and potentially sustainable modes of transportation and the environmental, economic, and social benefits they possess over conventional methods.

**Objective:** The objective of the PSTAT project was to encourage new student drivers to consider the benefits of alternative transportation methods and general sustainability issues when making future commuting decisions.

**Scope:** Achieving our objective began with the development of an engaging and educational program for high school students that focused on low impact transportation. The program was designed to make learning about the impacts of transportation mode choice fun and exciting to maximize the adoption of positive attitudes about low impact transportation alternatives. As such, we created an e-bike design and construction competition between high schools in the local area which also included aspects that highlighted various forms of alternative transportation. Three teams from different high schools were generated, and undergraduate engineering students were assigned as mentors to each team. Each team had a high school faculty mentor as well who aided with recruiting high school team members and providing a space to meet and construct the bikes. Along with the construction project, the high school students were required to produce a report detailing their design process which included a scenario-based sustainability analysis for their school which was also scored for the competition (see Section 1 above for details). By bringing out the competitive drive in the students and allowing them design, build, and analyze electric bicycles for competition, it was hoped that they would take ownership of their project and take each task seriously. This provided an effective and entertaining educational tool that would present the students with the knowledge of the benefits of alternative and energy efficient transportation at a formative age and implement it throughout their lifetime.

The overall design of the project was well-suited to represent the themes of the P3 program as its success would result in the students' understanding of the benefits of choosing low impact transportation methods in their daily commute over conventional ICE vehicles and applying this to their future decisions. Reduction of the number of ICE vehicles in our current transportation fleet would lead to fewer emissions harmful to human health and greenhouse gas emissions toxic to the environment. The sustainability analyses completed by the students would also give them the understanding that low impact transportation methods are not only better for human health and the environment but are also cost effective means for commuting. Furthermore, a shift away from gas-powered vehicles would lead to increased political stability through relief from the dependence on non-domestic sources of petroleum which would also have a positive impact on foreign debt.

Issues regarding automobile emissions and non-renewable resource depletion are problematic throughout the world. Combating these will require a drastic change in the

transportation sector. A definite challenge to widespread penetration of low impact transportation is a general lack of knowledge of the expected benefits. The PSTAT program offers a tremendous educational tool that has potential for serious growth. The relative simplicity of its design makes it an appropriate project for teaching high school students about sustainability in both the developed and developing world.

### 3. Data, Findings, Outputs/Outcomes

The results of this project were primarily assessed by comparing surveys given to students before and after the e-bike construction project/competition. A copy of the survey questions can be found in the Appendix of the report. These surveys were designed to quantitatively measure the desired short term results of the project, which were an increased understanding of the benefits of low impact transportation and a changed perception of the impacts of the transportation mode choice by the student body of local high schools. It is important to note that the two surveys were given several months apart and the students did not have access to their previous responses. The questions of highest interest were Questions 7 and 8 because they require the student to rank different vehicle attributes and modes of transportation in order of importance. The pre- and post-project results are summarized in Figures 1, 2, 3, and 4. Figure 1 shows a radar chart of the survey results regarding the vehicle attributes that the students deemed most and least important when deciding on their choice of transportation (the farther away from the center, the more important that attribute was on average). As shown, the cost to purchase and maintain the vehicle was considered to be the most important attribute both pre- and post-project. However, there was a noticeable change in the opinions towards the impacts the vehicle has on the environment and on overall human health upon completion of the project. While at first glance this may not appear to be a dramatic change, the project undoubtedly influenced a portion of the students. This is better realized through examination of Figures 2 and 3. Figure 2 shows the change in rank of individual opinions with regard to impact

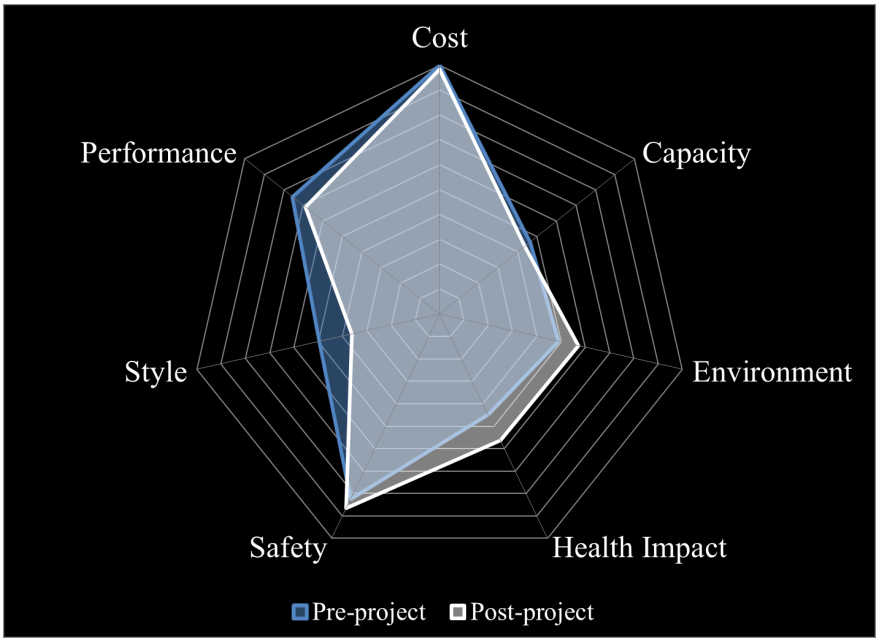


**Figure 1.** Pre- and post-project survey results of attributes of future commuting choices.

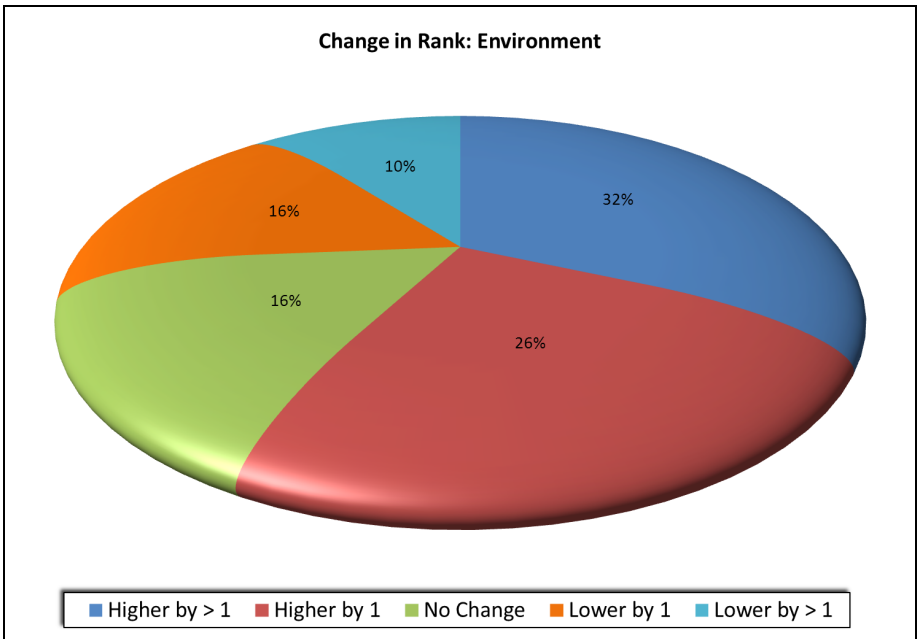


**Figure 2.** Change in rank between pre- and post-project surveys for impacts on the environment.

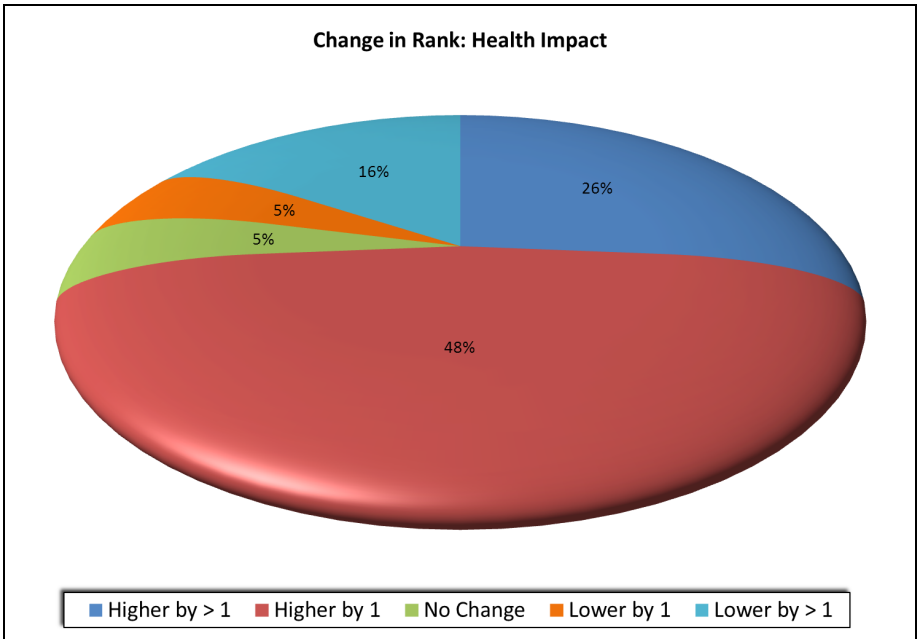


**Figure 3.** Change in rank between pre- and post-project surveys for impact on human health.

of the vehicle on the environment. The results reveal that after participation in the project, 26% of the students ranked the impact on the environment as more important by 1 and 32% ranked this attribute higher by more than 1, when compared to their responses before the project. Similarly, 48% of students surveyed ranked the vehicle's impact on human health higher by 1 and the rank improved by more than 1 for 26% of the students (Figure 3). This combines to 58% and 74% of the students surveyed who felt the impacts on the environment and human heath were more important in making their transportation choice after the project, respectively. Along with the features of the vehicle the students deemed important, the students were also asked to rank the transportation mode or vehicle type they would most likely use to commute when they enter the workforce (assuming a 10 mile or less commute). These results are summarized in Figure 4. The largest change was seen in the average opinion towards the conventional ICE vehicle where the overall likelihood of the use of that method decreased. On the other hand, both e-bikes and battery electric vehicles had increased likelihood for use after the project. These results further support the conclusion that

this project has influenced students to make more sustainable choices in areas related to transportation.

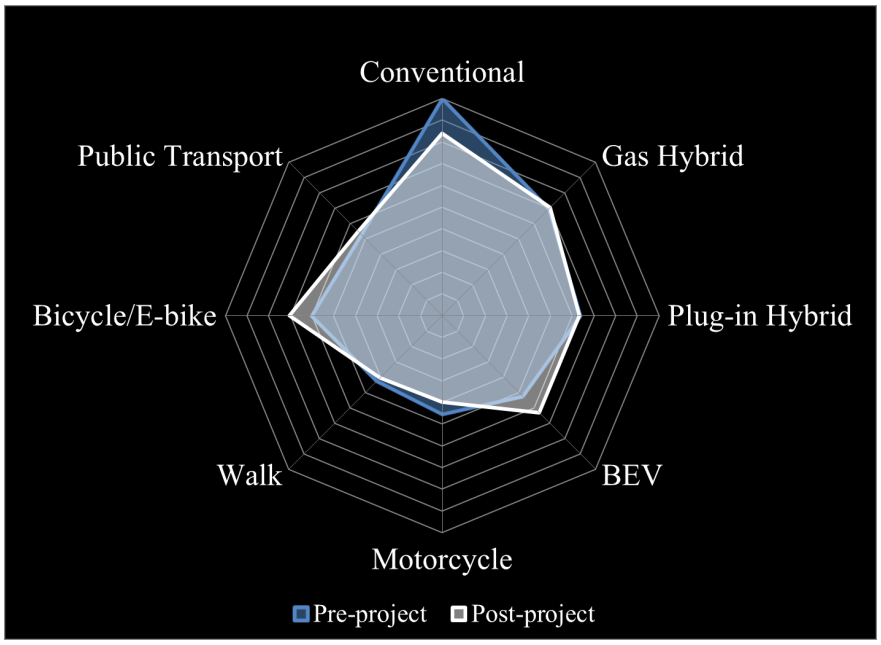


**Figure 4.** Pre- and post-project survey results of the future commuting methods.

## 4. Discussion, Conclusions, and Recommendations

In the following discussion, we address the given criteria for judging the success of our project. The discussion is written as a narrative, numbered to coincide with the given rubric to facilitate judging the degree to which we met each criterion.

i. Our project was designed to include each of the elements central to the P3 program objective. In targeting new and upcoming drivers, we hoped to increase the importance of the P3 themes in their choices of transportation options. Lowering the use of fossil fuels decreases the import of petroleum, which increases domestic prosperity. Replacing resource intensive transportation choices like standard gasoline powered vehicles operated with one occupant with more efficient and/or higher occupancy vehicles will decrease the negative impacts of fossil fuel combustion emissions on both public health (people) and greenhouse gas and environmental toxicant emissions (planet).

ii. The project was successful in fulfilling the desired results proposed for Phase I. The definition of success of the project provided in the Phase I proposal were:

(a) The creation of three functioning highly energy efficient electric bicycles with the capability to be used both manually and with electric assist
(b) An overall positive response to the statement, “This project helped me learn about the cost and environmental and health effects of different modes of personal transportation, such as buses, cars, and bikes,” as determined through an exit survey of the students

involved in the project, (an increased understanding of the benefits of low impact vehicles and a changed perception of the transportation system by the student body of local high schools. Note: this was originally indicated as solely positive responses to "I would consider buying an electric vehicle in the future" which we later changed to encompass education about low impact transportation as a whole.)

(c) Three completed sustainability analyses that indicate a positive (that is, reduced) environmental impact of the created vehicles.

The successful creation of the three highly energy efficient electric bicycles relied heavily on the mentoring and the motivation provided by the undergraduate advisors as well as the enthusiasm the high school students demonstrated in the construction process. When asked what they liked about the project in the post-project survey, several students mentioned designing, troubleshooting, and modifying the e-bike. Some examples include: "I enjoyed the construction aspect of the project and seeing our calculations come to life", "I enjoyed learning about a new form of transportation and how creating an e-bike could be done in your backyard.", and "The project was a great opportunity to apply science, mathematics, and critical thinking skills beyond the classroom and to the real world which is not common among many high school programs." We feel that the success of the student response to "This project helped me learn about the cost and environmental and health effects of different modes of personal transportation, such as buses, cars, and bikes" (see Figure 5) was influenced by the completion of the sustainability analyses. It should be noted that the population size of the participating students in each high school varied, and most of the students who did not "strongly agree" with this statement came from the largest team which divided up many tasks. As such, some of the students may not have been able to explicitly learn from and fully appreciate the sustainability analysis. This is also believed to be true for the results previously discussed in regarding Figures 1-4. Nevertheless,

**Table 1.** Sustainability analysis of Farragut High School. (Note: the data is an example of the high school students' work and should not be used as given.)

| | Current Scenario | Extreme E-bike Scenario | Battle of the Automobiles |
|---|---|---|---|
| **Human Health Impacts (Annual)** | | | |
| **Unburned hydrocarbons (ton)** | 7.99 | 2.01 | 0.01 |
| **Carbon Monoxide (ton)** | 22.82 | 5.75 | 0.06 |
| **PM 10 (ton)** | 0.08 | 0.02 | 0.0043 |
| **PM 2.5 (ton)** | 0.05 | 0.01 | 0.0040 |
| **Nox (ton)** | 2.36 | 0.63 | 0.06 |
| **$CH_4$ (ton)** | 1.82 | 0.46 | 0.00035 |
| **$N_2O$ (ton)** | 37.37 | 9.65 | 0.41 |
| **Mercury (g)** | 1.64 | 50.95 | 67.39 |
| **Environmental Impacts (Annual)** | | | |
| **Carbon Dioxide (ton)** | 1247.01 | 133.34 | 826.30 |
| **Economic Impacts (Annual)** | | | |
| **total annualized purchase cost ($)** | $9,285,334.97 | $2,863,806.93 | $5,682,334.65 |
| **total annual maintenance cost ($)** | $1,010,036.46 | $248,250.05 | $959,815.22 |
| **total annual fuel or energy cost ($)** | $2,056,366.00 | $565,565.86 | $985,618.72 |

the sustainability analyses allowed the students to see the effect the different scenarios have on the environmental, societal, and economic aspects of the choices they make. An example of one of the analyses is shown in Table 1. The actual e-bike competition also had a major contribution to the success of criteria (a) and (c) listed above as they were both factors in determining the winner.

Another factor in determining the success of the project lies in whether or not the students enjoyed the project as a whole; an enrichment activity that students enjoy is more likely to be successful in the long term. Additional questions in the post-project survey were asked to ascertain this and to gain insight into the possible future expansion of the PSTAT project. Their responses are summarized in Figure 5. As shown, the students overwhelmingly agreed that they would likely participate in this project again if the project were held next year. Furthermore, there was an overall consensus that the students would recommend this project to a friend. This is an extremely positive finding as we hope the students will take what they learned and convey it to others, thus broadening the impact of the project.

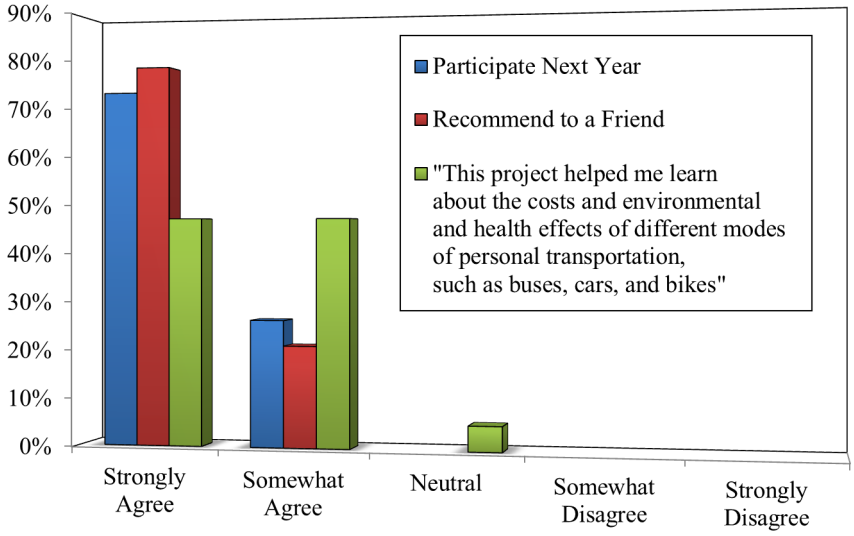


**Figure 5.** Post-project evaluation of student opinions.

If the project were to be repeated, college student advisors would be given a set of standardized material for teaching the high school student (the original plan required each team to develop their own materials and this was inefficient). This would ensure that all advisors were sufficiently prepared for the project and each high school team would start in a more equitable position. Better planning would also be required to allow ample time for the high school students to explore and appreciate the sustainability analyses, which would aid in their comprehension of the impacts of their commuting choices. Furthermore, the sustainability analysis would be simplified; originally it was designed to be realistic with respect to how students might use an electric bike but the additional complexity was judged not worth the increased realism. It was also mentioned in the post-project survey that "If sources were provided in the research to point us in the right direction would be greatly helpful". Bearing this in mind, a graduate student working with the project repeated the sustainability analyses to ascertain where the students had the most trouble. It was determined that directing the students to use the Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) Model[5] produced by Argonne National Lab would provide them with an effective, comprehensive tool to complete their analyses.

iii. Each high school team had undergraduate advisors with different backgrounds, albeit not with even shares of each engineering field. However, the weekly progress meetings where the whole team came together enabled general questions regarding the constructing of the e-bike, which was mainly mechanical and electrical, and the sustainability analyses to be addressed among the team from the viewpoint of the different disciplines.

iv. The World Commission of Environment and Development (WCED) in 1987 defined "sustainable development" as development that "meets the needs of the present without compromising the ability of future generations to meet their own needs".[6] While reliable and convenient transportation is essential in today's fast paced world, the current transportation system in the United States, which is heavily reliant on petroleum, entirely fails to capture the essence of this definition. A shift away from gas-powered vehicles and towards alternative modes of transportation would have a significant impact on sustainability. Based on the assumption that the students will apply what they gained from this experience to future decisions, this will lead to fewer commuters using conventional automobiles. While the Phase I project consisted of only a small representation, on a larger scale this impact would be much more pronounced. The reduction of ICE vehicles being driven would reduce the emissions of $NO_x$, CO, unburned hydrocarbons, and other materials harmful to human health. This would also lead to fewer greenhouse gas emissions harmful to the environment (see the response to question vii). Educating new teenage drivers on these impacts is a step in the right direction for the progression of sustainability.

v. The potential impacts of the PSTAT project are broadly applicable and transferable to various situations in both the developed and developing world as its focus was to induce a change in outlook towards sustainability and its application in everyday life. The last decade has seen a major increase in the amount of sustainable endeavors in every sector of today's world. However, much of this concerns political and technological issues. The real change to a more sustainable society must also include the individuals and communities; this begins with education. The future generation has to start to view sustainability as their responsibility towards the planet for sustainable efforts to be effective. The true beauty of the PSTAT project lies in its simplicity and transferability. In both developed regions such as the United States and Europe, as well as developing regions such as South East Asia, this form of project could potentially impact students all over the world in the early state of their education and set the course of their worldview.

vi. For this project two external partners were involved. The University of Tennessee Research Office provided $2,000, and the Knox County school system provided high school faculty advisors and a meeting venue for each of the three local high schools.

vii. It is difficult to extrapolate quantifiable impacts in terms of direct sustainability metrics from the survey data. We do not know to what extent their changes in attitude will actually affect future transportation choices. However, an example of these potential impacts, as determined by the students, can be seen in the sustainability analysis shown in Table 1 (the scenarios are described in Section 1). The analyses required the students to not only consider in-use vehicle emissions but also, in the scenarios involving e-bikes and the Nissan Leaf, the impacts of the methods of electricity generation. These two scenarios involving the electric vehicles were

determined to have the fewest environmental and human health impacts related to emissions, as well as, the lowest economic impact; this is particularly true for the "Extreme E-bike Scenario". However, the primary quantifiable measure from the project was the student responses to the rankings summarized in Figures 1-4. From this, it can be determined that there was a measureable change in the students' opinions on sustainable transportation. With this in mind, a shortened evaluation of the emission analysis for a single individual's annual commute to school based solely on the use of a conventional automobile, a Nissan Leaf, or an e-bike was completed (see Appendix for values and assumptions). Switching from a conventional automobile to a Nissan Leaf would reduce their annual emissions from commuting to school for VOCs (93.4%), CO (93.8%), $NO_x$ (26.9%), and $CO_2$-eq (46.2%). An even greater impact was determined for the switch to an e-bike for VOCs (99.5%), CO (99.9%), $NO_x$ (92.6%), and $CO_2$-eq (95.7%).

viii. This project also had a significant impact on the important intangibles knowledge and experience. The college students were satisfied, gaining valuable experience working as mentors to high school students throughout the design phase of the project, while high school students expressed excitement in participating in an interesting after-school project. While most students indicated that an e-bike would not be a consideration for future commuting, the project got them thinking about the impacts of their commuting choices. The following comments were received from the students' post-project survey when asked what they liked about the project: "I liked how creative you had to be and how different transportations impacted the environment [sic]", "the project was insightful on the amount of gas used by different transportation", and "the new view of bikes and transportation". The understanding gained of how different transportation methods impact people, prosperity, and the planet is an important feature of the PSTAT project.

ix. The tangible impacts, which include the constructed e-bikes suited for a landscape like Knoxville, could potentially ease short-distance trips due to their versatility for different commuting needs if the e-bikes are to be utilized in a bike-sharing system as the "cycleUshare" program initiated in the University of Tennessee, Knoxville. Non-tangible impacts include an increased student understanding of the significance of taking sustainability impacts into consideration in making commuting choices. This change would be the beginning of creating a cleaner environment for living in the future which has a direct impact on overall human health and reduce costs associated with healthcare visits caused by exposure to pollution.

x. The technology to build and assemble electric bikes is readily available. Using this design process to get teens engaged in learning about potentially sustainable transportation choices is the novel aspect of PSTAT.

## B. Proposal for Phase II

### 1. P3 Phase II Project Description

*Overall Actual and Potential Sustainability Benefits of the Proposed Project*

The primary goal for Phase II is to extend the PSTAT project to include more schools in East Tennessee to broaden its influence with the hope that the excitement the project creates will allow for it to continuously expand and become self-sustaining. From University press releases, we were contacted by two different electric bike companies (including Currie Technologies, the largest manufacturer of electric bikes in the US). Our final competition with the high school

students was covered by a local television station and shown on a local news channel twice the day of the competition. This project has the ability to fundamentally affect students' priorities concerning transportation choices at the very time in which they will begin considering them, the end of secondary education. Most individuals in the United States who drive an ICE vehicle in their daily commute could drastically reduce their associated negative impacts utilizing the knowledge and experience gained in the PSTAT project. Providing an understanding of a vehicle's impact on the environment and human health at a young age could lead to a decrease in the use of conventional ICE automobiles in the United States for daily commuting[7] and an increase in transportation methods with demonstrated lower impacts in the elements of the P3 program. This is particularly true in urban areas where automobiles are the primary source of air pollution[8] even though public transportation is often available and many commutes are within a reasonable range to use nearly benign modes of transportation, such as walking and bicycles/e-bikes. In fact, it has been estimated that increasing the mode share of all trips made by bicycling and walking from 12% to 15% could lead to a reduction of 3.8 billion gallons per year of fuel and a decrease in greenhouse gas emissions by 33 million tons per year, which is equivalent to replacing 19 million conventional cars with hybrids.[9] The primary potential benefit of the project is a significantly increased awareness of these different transportation choices' effects on the environment, human health, and the economy. This project encourages students to be just as interested in hybrid and electric vehicles and their overall impacts through the sustainability analysis as it does in the construction of electric bicycles. The PSTAT project has the potential to revolutionize the way a new generation of teenage drivers approaches transportation and issues regarding sustainability.

*General Relationship of Challenge to Sustainability*

The current transportation system in the United States is heavily dependent on petroleum, and the primary vehicle technologies are responsible for emissions harmful to the environment and human health. Personal transportation alone accounts for approximately 46% of the total United State petroleum consumption.[10] The overutilization of this finite resource for transportation is a serious problem that not only diminishes the raw material supply for many chemical products but also is a cause of political unrest and decreased national security due to the import of petroleum from politically volatile areas. The net imports of petroleum in the United States accounted for approximately 45% of its consumption in 2011.[11] While this number has declined since 2005, reducing the amount of petroleum used for personal transportation would lead to increased energy independence. The transportation sector is also responsible for 32% of total $CO_2$ emissions in the United States. Of this, nearly 65% of the emissions came from gasoline consumption for personal vehicles alone.[12] Along with environmental concerns, tailpipe emissions from conventional automobiles include compounds that can have negative impacts on human health. The combination of these effects necessitates a change in our methods of transportation to more sustainable solutions. However, moving towards sustainable transportation methods in a culture with the infrastructure and habits tuned for traditional ICE vehicles is a nontrivial task.

Two of the primary barriers to the general adoption of many sustainable technologies are public perception and knowledge. The United Nations Educational, Scientific, and Cultural Organization (UNESCO) reported that "education is the most effective means that a society possesses for confronting the challenges of the future" and continues that "public awareness and understanding are, at one, consequences of education".[13] Education in the report did not concern formal education alone but a more broad definition including learning acquired at home and in

the community. While the e-bike construction project/competition is an entertaining way to generate student involvement, the overall PSTAT project is first and foremost an educational tool. It is essential for an advancing society to adopt technologies with the least negative impact on all elements of sustainability. Electric vehicles are three times more efficient at converting electrical energy to mechanical motion than an ICE automobile. Transferring energy production and consumption to its most efficient form is an important step in building a sustainable future. Invoking this knowledge into young minds, as well as learning the science of electric vehicles through the construction of one, is an important aspect of PSTAT.

*Challenge Definition and Relationship to Phase I*

Due to the success and overwhelming enthusiasm and interest of the Phase I project, we believe that we have only scratched the surface of the potential implications of the PSTAT project. As such, the proposal for Phase II of the PSTAT project is an extension of Phase I. The primary goal of Phase I, and thus Phase II, is to make new teenage drivers aware of the impacts of their choice in transportation methods and aims to shift their thinking away from conventional ICE automobiles. In Phase I, this was accomplished through an e-bike design and construction project followed by an e-bike competition, which also included the completion of a scenario-based sustainability analysis, between three high schools in the Knoxville area. Phase I documented that the PSTAT project is an effective way to interest young minds in the aspects of sustainable transportation and to make transportation choices that reflect such an interest. Overall, the students really enjoyed the project and were eager to be involved again. If a group of young minds can be influenced on a small scale, trial run of a project, then the effect will only be greater as the project continues to grow and anticipation and excitement throughout the process are elevated.

The Phase I project, however, was not without faults. As indicated in the Discussion, Conclusions, Recommendations section, there will be organizational and schedule changes when continuing the PSTAT project. These will specifically aim at ensuring that each team is equally equipped with a standardized packet of information and the team sizes are more balanced (teams ranges from two students at one school to 12 at another). Furthermore, the sustainability analysis will be simplified to make it easier to understand and conduct. Lastly, the final report will be omitted as this seemed to be a problem for some schools, especially for those students who did not have access to a personal computer. The students will still be required to document their design calculations and conduct a (simplified) sustainability analysis and present and defend these in poster-format during the competition.

In the first year of Phase II, we plan to add three additional high school teams (for a total of six) from the local area to the project, and in the second year three more high school teams will be added (for a total of nine). With increasing size and interest, it is hoped that the project's influence will continuously grow. Our success will be measured, again, by surveys completed by the students before and after the e-bike construction project regarding the attributes they deem most important when purchasing a vehicle, as well as the methods they will likely use for commuting in the future.

*Innovation and Technical Merit*

The PSTAT project is an innovative approach at bringing awareness to new teenage drivers of the implications brought about by their daily commute. By allowing students the freedom to lead the efforts in the design and construction of the e-bikes for a competition between their peers from local schools brings about a competitive nature and excitement while

also allowing them to utilize the knowledge they have obtained from math and science courses. The simplicity or complexity of the e-bike is governed solely by the interest of the team and the way they approach the criteria of the events whereby each e-bike is judged. Those built during Phase I displayed widely different approaches to the challenges of the project from each school. In this way, the PSTAT project exposes secondary students to an engineer's process of achieving a goal, building to a design based on criteria. Through this hands-on approach, the undergraduate mentors are able evoke interest and imbue an understanding of sustainable transportation that may not be as effective if the material was simply given to them in a classroom setting.

*Results, Evaluation and Demonstration*

As with Phase I, the primary and immediate results will be the student participant surveys that quantify the potential environmental, economic, and social benefits based on the students' acceptance and utilization of the knowledge obtained. As mentioned previously, the continuation of the PSTAT project into Phase II will primarily focus on educating high school students about low impact alternatives available for daily commuting. Using education as a tool to promote change can be very influential. To quote Nelson Mandela "Education is the most powerful weapon which you can use to change the world." The further market penetration of ultra-low emission vehicles and the advancement of renewable energy technologies are critical for increasing the sustainability of transportation. However, the penetration of these into our society as a whole will be slow without the interest and appreciation of the positive features they possess. The PSTAT project aims to educate people at an important age on the possibilities and rewards that sustainable thinking can accomplish. The evaluation of the effectiveness of our project toward this goal comes from the pre- and post-project surveys the students will complete (see Appendix) and the comments we receive about what they learned. Each student response indicating their new understanding of the environmental, economic, and social impacts of sustainable transportation is a positive step to a more sustainable future.

We will continue to include student rankings of the important vehicle attributes and methods of transportation in the pre- and post-project surveys. These provide a means to quantify the potential impact the project has on participants. From this we may be able to make projections as to whether or not the participants actually make more sustainable decisions in the future. Furthermore, the sustainability analyses provide a quantitative measure for the students to understand the costs and harmful emissions of different methods of transportation which can lead to a qualitative change in behavior. So while these will be projected/potential benefits to environment, economic, and societal dimensions, the effects of the project can be evaluated both qualitatively (through student and high school faculty short answer feedback) and quantitatively (through survey results).

*Integration of P3 Concepts as an Educational Tool*

The PSTAT project is by design an educational tool; the goal of the project is to raise awareness of low impact, potentially sustainable transportation and to get the students to consider more sustainable options. The success of the PSTAT project relies on the transmission of interest and enthusiasm from the engineering advisors directly to the high school students on issues regarding sustainability. As an educational tool, the project accomplished its goal in Phase I by educating the student teams on the effects of their transportation modes on the three dimensions of sustainability. Additionally, each student group was encouraged to make the effort to promote awareness of alternative modes of transportation within their schools and communities. In Phase I, the students hung educational posters around the school, utilized the

popular social media sites, such as Facebook, and were involved in a competition covered by the local media and in University press releases. Several individuals not participating in the project also came out to watch the competition. This allowed the students to promote and educate not only their fellow high school peers but others in the community as well. The different avenues allowed the students to reach several of people with information on sustainability and sustainable thinking. Because of these efforts the results from the data showed a fundamental shift toward alternative lower impact transportation modes from conventional methods.

Several aspects of the project also aid the development of higher level cognitive skills. The students are expected to produce detailed analyses of the impacts of each transportation mode. This is accomplished with the help of current college engineering students. By using engineering students as project leaders, the high school students can benefit from their specialized academic field of study. One parent at the competition commented how impressed he was with the interaction between the undergraduate engineering and high school students and he commented that he wished there were more similar programs to get university students so intimately involved with young potential engineers and scientists. All of the high school faculty advisors felt that having college engineering students work with their students was much better than having university faculty or high school teachers talk about the importance of math and science. Because the university students were close in age to the high school students yet were still viewed as experts, the high school faculty advisors commented that the high school students more easily appreciated the connection between their high school course in physics and math and careers in engineering and science. This college-to-high school connection is a very unique aspect to the PSTAT project. Along with the design and construction of the e-bike, which in itself is an educational process, the students will also be required to complete two deliverable items for the project competition: a sustainability analysis and an informational poster. By completing the sustainability analysis the students are exposed to a level of research and critical thinking beyond typical high school settings. This exposure and understanding will be extremely beneficial as the students pursue higher education. The posters are also expected to be college level work, and the student defenses to the faculty judges will introduce the students to the expectations of higher level academic presentations. By familiarizing the students with this college level work they can begin to develop these skills and carry them into university.

*Interdisciplinary Teamwork*

Since the project is an educational tool used to expose high school students to alternative lower impact transportation, and more importantly sustainability in general, the project benefits from the collaboration of multiple disciplines of engineering. Mechanical engineers are knowledgeable about moving parts and vehicle dynamics. Electrical engineers have an understanding of the motors and controllers required to take a normal bicycle and turn it into an e-bike. Civil engineers have exposure to different modes of transportation and how the larger transit system interacts. Chemical engineers have an understanding of the production of various fuels and materials and the associated emissions and economics. The information packet provided to the teams and mentors will be a compilation of documents generated by the undergraduate advisors based on their field of study. For example, the mechanical engineers will be responsible for producing information regarding the construction of the e-bike, the chemical engineers will supply information regarding the sustainability analyses, and so on. Bringing all these different fields of study together allows multiple perspectives on sustainability and engineering to be combined into a single project, and it also will introduce the high school participants to these different points of view. Most of this material was generated as part of

Phase I, but will be optimized and presented to the students at the beginning of the project in Phase II.

**2. Project Schedule**

The project schedule is summarized in the following chart:

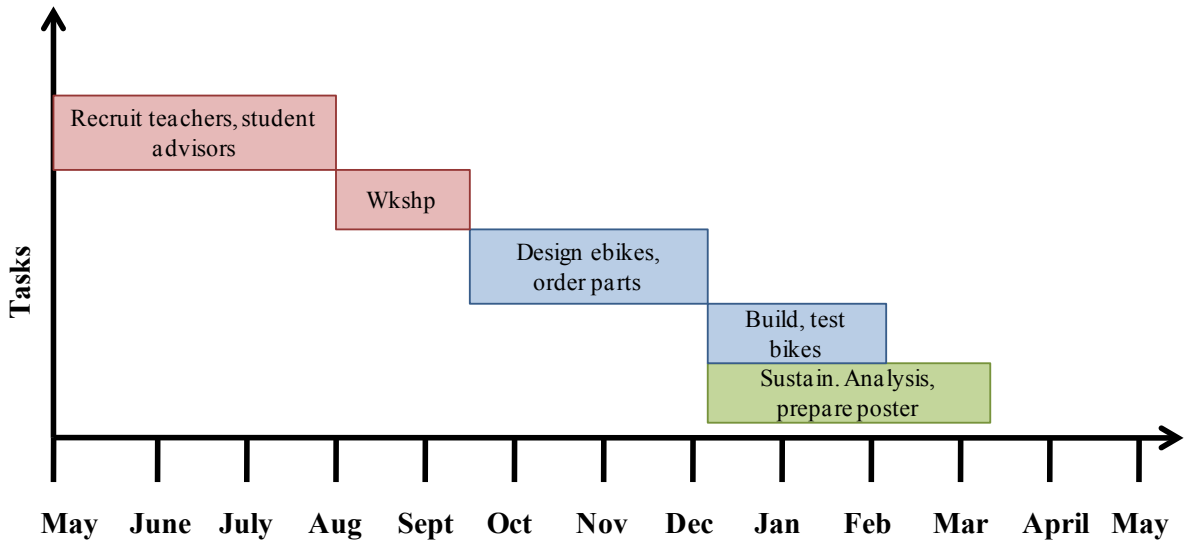


**Figure 6.** Project schedule for Year 1 of Phase II. The schedule for Year 2 is the same as year one except three additional teams will be added.

The timeline of the Phase I project required the interaction with and survey of the high school teams be completed by early February. The extra time at the end of the project will allow for a more careful sustainability analysis, which should lead to a greater appreciation of how an individual's personal mode choice impacts the sustainability of transportation.

## C. References


1. Friedrichs, J., *Energy Policy* **2010**, 38, 4562-4569.
2. Ehsani, M.; Gao, Y.; Emadi, A., *Modern Electric, Hybrid Electric, and Fuel Cell Vehicles: Fundamentals, Theory, and Design*. CRC Press: Boca Raton, FL, 2009.
3. NASA. *Road Transportation Emerges as Key Driver of Warming*, Research News [Online], 18 February 2010. available at: http://www.giss.nasa.gov/research/news/20100218a/.
4. U.S. Environmental Protection Agency. *Air Trends: Basic Information*. http://www.epa.gov/airtrends/sixpoll.html.
5. Argonne National Lab. *GREET Beta Announcement*. http://greet.es.anl.gov/.
6. United Nations General Assembly, *Report of the World Commission on Environment and Development*, 96th plenary meeting, 11 December 1987, Document A/RES/42/187; available at: http://www.un.org/documents/ga/res/42/ares42-187.htm
7. U.S. Department of Transportation Federal Highway Administration, *Summary of Travel Trends: 2009 National Household Travel Survey*, June 2011, FHWA-PL-11-022; available at: http://nhts.ornl.gov/2009/pub/stt.pdf
8. Tsai, J. H.; Chang, S. Y.; Chiang, H. L., *Atmos. Environ.* **2012**, 61, 499-506.
9. Rails-to-Trails Conservancy. *Active Transportation for America: The Case for Increased Federal Investment in Bicycling and Walking*, 2008. available at: http://www.railstotrails.org/resources/documents/whatwedo/atfa/ATFA_20081020.pdf.
10. U.S. Energy Information Administration, *Annual Energy Review 2011*, September 2012, DOE/EIA-0384; available at: http://www.eia.gov/totalenergy/data/annual/pdf/aer.pdf
11. U.S. Energy Information Administration. *How Dependent are We on Foreign Oil?*, Energy in Brief [Online], 13 July 2012. available at: http://www.eia.gov/energy_in_brief/article/foreign_oil_dependence.cfm.
12. U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2010*, 15 April 2012, EPA 430-R-12-001; available at: http://www.epa.gov/climatechange/Downloads/ghgemissions/US-GHG-Inventory-2012-Main-Text.pdf
13. United Nations Educational Scientific and Cultural Organization, *Educating for a Sustainable Future*, November 1997, EPD-97/CONF.401/CLD.1; available at: http://www.unesco.org/education/tlsf/mods/theme_a/popups/mod01t05s01.html#edu

## Budget and Budget Justification

### Budget Justification:

**Personnel:**
In Year 1, we will hire six university student advisors at $1,000 per student for a total stipend of $6,000. In Year 2, nine student advisors will be hired for a total stipend of $9,000.

| Position/Title | Stipend | # of Personnel (Year 1) | # of Personnel (Year 2) | Total Personnel |
|---|---|---|---|---|
| Student advisor | $1,000 | 6 | 9 | 15 |
| Total Cost | | $6,000 | $9,000 | $15,000 |

**Travel:**
In Year 1, the university student team including one faculty advisor will travel to the National Sustainable Design Expo to exhibit the results of the first year of the Phase II award. The total costs are estimated below:

| Purpose of Travel | Location | Item | Computation | Cost |
|---|---|---|---|---|
| National Sustainable Design Expo | DC | Lodging | 4 nights*4 rooms*$180/room | $2,880 |
| | | Transportation | Van rental | $632 |
| | | Local transportation (Metro, taxi), vehicle parking (at hotel), per diem | 7 people *4days*$88.86/day | $2,488 |
| Total Cost | | | | $6000 |

**Supplies:**
Supply costs are included for the bike parts and supplies for the competition itself (traffic cones, chair rental, pizza during the poster session and award ceremony, poster printing):

| Supply Items | Year 1 Computation | Year 2 Computation | Total Cost |
|---|---|---|---|
| Electric Bike parts (bike frame, motor, battery, controller, lights, panniers, fenders, etc.) | 2,500 per team *6 teams | 2,500 per team*9 teams | 37,500 |
| Competition (traffic cones, chair rental, etc.) | 300 | 300 | 600 |
| Pizza for poster session | 221.34 | 331.34 | 552.68 |
| Posters/other printing | 300 | 450 | 750 |
| Total Cost | $15,821.34 | $23,581.34 | $39,402.68 |

**Indirect Costs:**
Calculated at the negotiated rate for the University of Tennessee - Knoxville of 49% of Total Direct Costs: $60,402.68 x 0.49= $29,597.32 (rounded up to whole $0.01)

## Appendix

## Pre- and Post-project Surveys

### PSTAT Transportation Preferences Survey

The following survey is designed to determine your preferred method of commuting to school or class, your preferences in vehicle choice, and methods you think you might use for commuting in the future. By completing the survey, you agree to the use of the data in written and oral reports. Your name should not appear on the survey. No identifying information about the participants will be associated with this survey or reported in any written or oral report.
**Participation in completing the survey is strictly voluntary.**

1. I am currently attending
    a. Farragut High School
    b. Fulton High School
    c. West High School
    d. The University of Tennessee
2. The method(s) I regularly use to get to school or class includes (indicate all that apply):
    a. personal automobile
    b. motorcycle
    c. bicycle
    d. walk
    e. school bus
    f. public transit (KAT, etc.)
    g. other
3. The distance I travel to school or class (one way) each day is most nearly:
    a. `1 mile or less
    b. 1-2 miles
    c. 2-5 miles
    d. 5-10 miles
    e. 10-15 miles
    f. Greater than 15 miles
4. The method I prefer to use to get to school or class is:
    a. personal automobile
    b. motorcycle
    c. bicycle
    d. walk
    e. school bus
    f. public transit (KAT, etc.)
    g. other
5. If you frequently use a personal automobile to get to school or class, what is the average number of passengers in the vehicle?
    a. 1
    b. 2
    c. 3
    d. 4 or more
    e. I do not frequently use a personal automobile to get to school or class

6. If you frequently use a personal automobile to get to school or class, what is your best estimate of the gas mileage of the vehicle on the route used to commute to school or class?
    a. 10 mpg or lower
    b. 10-15 mpg
    c. 15-20 mpg
    d. 20-25 mpg
    e. 25-30 mpg
    f. 30-35 mpg
    g. 35-40 mpg
    h. More than 40 mpg
    i. I do not frequently use a personal automobile or motorcycle to get to school or class
7. In future choices of methods of commuting to work or school, rank the following 7 attributes of your choice in importance (1= most important, 7=least important)

    _____ Cost to purchase, operate, and maintain vehicle
    _____ Vehicle capacity (number of people the automobile will carry)
    _____ Impact on the environment
    _____ Impacts of vehicle production and use on human health
    _____ Vehicle safety
    _____ Vehicle style
    _____ Vehicle performance
8. Rank the following 8 methods of commuting to work based on how **likely** you are to choose the method as your primary method of commuting when you finish your formal education. Assume your future commute will be less than 10 miles, one way. (1= most likely, 8= least likely)

    _____ conventional automobile
    _____ hybrid gasoline automobile (like a Toyota Prius)
    _____ plug-in hybrid electric and gasoline automobile (like a Chevy Volt)
    _____ battery electric automobile (like a Nissan Leaf)
    _____ motorcycle
    _____ walk
    _____ bicycle (including an electric bike)
    _____ public transportation (bus, subway, etc.)

**PSTAT Transportation Preferences Survey: Post Project**

The following survey is designed to determine your preferred method of commuting to school or class, your preferences in vehicle choice, and methods you think you might use for commuting in the future. By completing the survey, you agree to the use of the data in written and oral reports. Your name should not appear on the survey. No identifying information about the participants will be associated with this survey or reported in any written or oral report.

**Participation in completing the survey is strictly voluntary.**

1. I am currently attending
    a. Farragut High School
    b. Fulton High School
    c. West High School
    d. The University of Tennessee
2. The method(s) I regularly use to get to school or class includes (indicate all that apply):
    a. personal automobile
    b. motorcycle
    c. bicycle
    d. walk
    e. school bus
    f. public transit (KAT, etc.)
    g. other
3. The distance I travel to school or class (one way) each day is most nearly:
    a. 1 mile or less
    b. 1-2 miles
    c. 2-5 miles
    d. 5-10 miles
    e. 10-15 miles
    f. Greater than 15 miles
4. The method I prefer to use to get to school or class is:
    a. personal automobile
    b. motorcycle
    c. bicycle
    d. walk
    e. school bus
    f. public transit (KAT, etc.)
    g. other

5. If you frequently use a personal automobile to get to school or class, what is the average number of passengers in the vehicle?
    a. 1
    b. 2
    c. 3
    d. 4 or more
    e. I do not frequently use a personal automobile to get to school or class

6. If you frequently use a personal automobile to get to school or class, what is your best estimate of the gas mileage of the vehicle on the route used to commute to school or class?
    a. 10 mpg or lower
    b. 10-15 mpg
    c. 15-20 mpg
    d. 20-25 mpg
    e. 25-30 mpg
    f. 30-35 mpg
    g. 35-40 mpg
    h. More than 40 mpg
    i. I do not frequently use a personal automobile or motorcycle to get to school or class
7. In future choices of methods of commuting to work or school, rank the following 7 attributes of your choice in importance (1= most important, 7=least important)

    _____ Cost to purchase, operate, and maintain vehicle
    _____ Vehicle capacity (number of people the vehicle will carry)
    _____ Impact on the environment
    _____ Impacts of vehicle production and use on human health
    _____ Vehicle safety
    _____ Vehicle style
    _____ Vehicle performance
8. Rank the following 8 methods of commuting to work based on how **likely** you are to choose the method as your primary method of commuting when you finish your formal education. Assume your future commute will be less than 10 miles, one way. (1= most likely, 8= least likely)

    _____ conventional automobile
    _____ hybrid gasoline automobile (like a Toyota Prius)
    _____ plug-in hybrid electric and gasoline automobile (like a Chevy Volt)
    _____ battery electric automobile (like a Nissan Leaf)
    _____ motorcycle
    _____ walk
    _____ bicycle (including an electric bike)
    _____ public transportation (bus, subway, etc.)
9. If this program were held again next year, how likely would you be to participate?
    a. Very likely
    b. Somewhat likely
    c. Not very likely
    d. Very unlikely
10. If this program were held again next year, how likely would you be to recommend this project to a friend?
    a. Very likely
    b. Somewhat likely
    c. Not very likely
    d. Very unlikely

11. Rate the degree to which you agree with the following statement: “This project helped me learn about the cost and environmental and health effects of different modes of personal transportation, such as buses, cars, and bikes”.
    a. Strongly agree
    b. Somewhat agree
    c. Neutral
    d. Somewhat disagree
    e. Strongly disagree
12. Please comment below on what you liked about the project

13. Please comment below on what you think should be changed or improved about the project.

## Additional Competition and E-bike Design Specifications

### General Design Requirements and Project Description:

- Each bike must be assembled within a budget of $2100 (which includes applicable taxes, delivery and handling fees, etc.). This budget cannot be supplemented.
- Each bike must be constructed so that its operation poses no additional hazards when compared to a non-electric bike.
    - All electrical connections must be properly insulated and charging or discharging the battery must not present any hazard to the user.
    - Any exposed gearing or chain drives must not present additional hazards over those normally present on a bike to the rider.
- Each bike must be capable of conforming to relevant Tennessee State and US Federal laws that govern the maximum legal speed for electric assist bikes.
    - If your team's entry can exceed the federal and/or state maximum allowable speed for an electric bike, it must have installed on the bike mechanical or electrical means of restricting the speed to the legal limit.
- The bike must be equipped to safely carry the rider plus any additional payload.
- Your bike must be equipped with appropriate and effective braking and lighting systems for safe operation on public roads in normal expected weather conditions that would be encountered from 7:00 am to 5:30 pm during the high school year, including inclement weather.
    - The bike must be equipped with a forward facing white light and a rear facing red flashing light.
    - This will be tested at the competition by the competition judges. Any team not meeting this requirement will not be allowed to compete.
- When testing your bike, the rider must be wearing a properly fitted CPSC-certified bike helmet and closed toed shoes (no sandals).

### Competition Event Specifics:

Your bike must carry all batteries and equipment (carrying bags, lights, straps, etc) for each event during the entire competition. The bike must remain in the same configuration for the entire competition. Each entry is subject to inspection by the event judges at any time. Each event can use a different rider but the same rider must start and complete each event unassisted. Each rider must be wearing a properly fitted CPSC-certified bike helmet, pants that cover the legs, and closed toe shoes. A team may elect not to participate in any particular event, but will not be awarded points for that event. Teams must demonstrate that their bikes are electrically or mechanically speed-limited to meet the federal and state requirements for an electric motor-assisted bike. The bike must be speed-limited as stated above to meet the federal and state requirements for all events except for "Fastest Bike". Any team not operating in a safe manner will be immediately eliminated from the competition.

To validate that their bike could be used for commuting to school, the team will present to the event judges at the beginning of the competition calculations illustrating their bike can travel a minimum of 15 miles at an average energy use of 18 watt-hours per mile; that is, the bike will carry batteries with a 270 W-hrs minimum total capacity. The calculations will use standard documented or measured capacity ratings for their battery type (watt-hours per pound of battery) and an 80% depth of discharge. The battery used for the competition must be no smaller than that used in these calculations.

**Individual Impacts: Annual School Commute**

| | Conventional Automobile | | Nissan Leaf | | E-bike | |
|---|---|---|---|---|---|---|
| (Annual) | Operating | Well-to-Wheel | Operating | Well-to-Wheel | Operating | Well-to-Wheel |
| VOC (g) | 324.0 | 576.0 | 0 | 37.8 | 0 | 3.1 |
| CO (g) | 6741.0 | 6868.8 | 0 | 426.6 | 0 | 5.1 |
| $NO_x$ (g) | 253.8 | 689.4 | 0 | 504 | 0 | 51.1 |
| $CO_2$-eq (ton) | 0.75 | 0.93 | 0 | 0.5 | 0 | 0.04 |

Assumptions:

- Inputs into the ANL GREET Model
  - Modeling year: 2010
  - Average vehicle age in the fleet: 2005 with 23.4 mpg fuel economy
  - Electricity emissions based on Knoxville's generation methods
- Round trip of 10 miles/day for 180 school days/year
- Electricity of the e-bike: 0.033 kWh/mile