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Development and Delivery of an Interactive Renewable Energy Program for Under-Represented Minority High School Students in Philadelphia

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Abstract

Philadelphia has the highest poverty rate among the largest ten cities in the country. Underserved communities often lack the knowledge of how their choices impact energy use, options to increase their home's sustainability, and alternatives to traditional energy sources for powering their homes. This offers challenges and opportunities to educate and excite residents in underserved communities about renewable energy's potential to positively impact their communities. To that end, students and faculty at Villanova University have developed the Power Forward Program, a highly interactive program consisting of activities and lectures to teach underrepresented high school students and teachers in the Philadelphia region about various aspects of renewable energy and electrical engineering. The curriculum includes basic electric circuits, energy production, transmission and distribution, energy efficiency, household energy use and environmental impacts, and economics of different types of energy. In addition to the students in the program, family members were invited to participate in the activities so that it became more of a family affair than simply a student-only program. Twelve students participated in the program that was remotely delivered over a period of two months. A pre-program survey of the participants was performed before the start of the program and a post-program survey was conducted after the program. Additional details of the program, the surveys, and the measured learning outcomes will be presented in this paper along with plans for program expansion.

Introduction

Philadelphia has the highest poverty rate among the largest 10 cities in the country[1]. Reflective of the high poverty rate, Philadelphia residents are more likely than the average U.S. citizen to face energy insecurity. Energy insecurity can be described as an inability to pay energy bills or keep the temperature in a home. A report in 2015 by the US Energy Information Agency (EIA) [2] showed that nearly 31% of Americans face some sort of energy insecurity such as forgoing food, medicine, or other necessities to pay for energy bills, as seen in Figure 1.

Low-income households also spend a significantly higher percentage of their income on utilities compared to high-income households (7.2 percent compared to 2.3 percent) [3]. The 2015 Residential Energy Consumption Survey (RECS) released in 2018 [4] shows that households with income lower than $40,000 account for roughly 34.9% of the residential energy consumption, while households between the ranges of $40,000 and $80,000; $80,000 and $120,000; and above

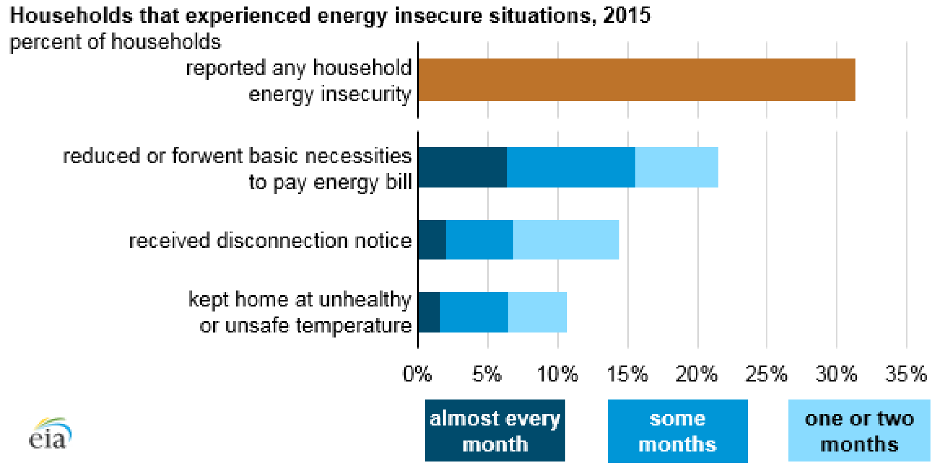

Figure 1: Households in the US that experienced energy insecurities in 2015.

$120,000 accounted for 28.2%, 17.1%, and 19.8% of the total residential consumption as seen in Fig. 2.

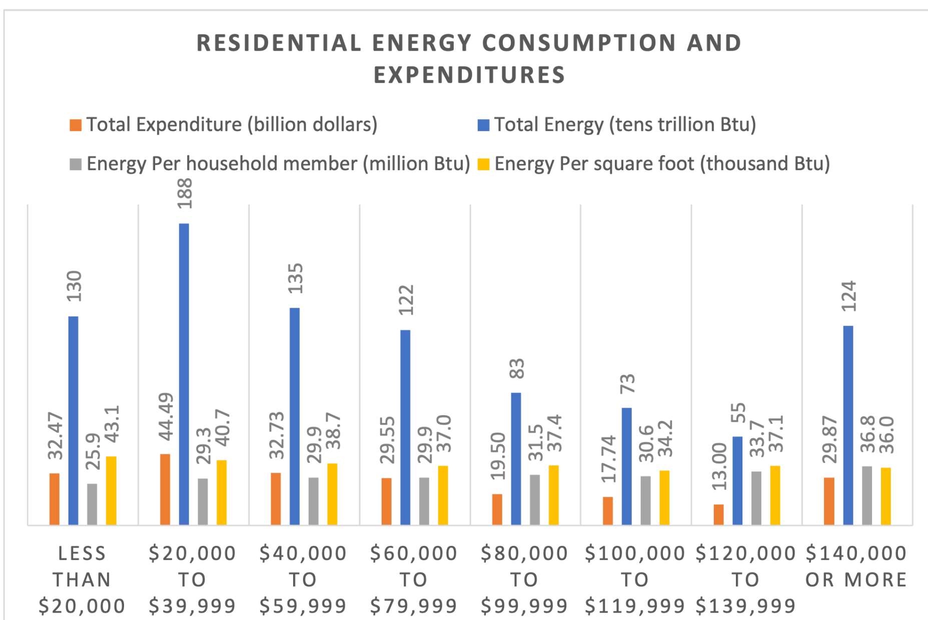

Figure 2: Residential Energy Consumption and Expenditure according to household income in 2015 in the U.S.

Underserved communities have increased access to energy in the USA over 25 years (1990-2015). However, an increase in electricity as the main energy source might have affected these communities economically due to the lower cost of natural gas which can be used for space heating and cooling [5]. Thus, underserved communities often lack the knowledge of how their choices impact energy use, options to increase their home's sustainability, and alternatives to traditional energy sources. These barriers result in lower usage of renewable energy and interest in sustainability issues among underserved communities. Increased knowledge of renewables by these communities promises both significant financial benefits to consumers coupled with an opportunity to improve the region's environment. Engaging underserved communities will also increase access to energy justice which has been explored recently in several publications [6, 7]. Besides, the current energy situation for low-income households in Philadelphia offers challenges and opportunities to educate and excite residents in underserved communities about renewable energy's potential to positively impact their communities.

Recent developments in Electric Vehicles, Smart Grids, Battery Storage, Wind, and Solar Energy show that Renewable Energy Technologies will continue to increase their penetration into the World's Energy Mix as countries continue to try to mitigate the effects of climate change [8]. One of the toughest challenges to overcome for Renewables is trying to mitigate opposition from the public concerning policies promoting greater renewable penetration to the energy matrix often due to misconceptions or lack of knowledge on how a particular technology works[9, 10]. Consequently, there is an unmistakable need to execute agreeable systems that are both manageable and enable neighborhood individuals to draw in with those policymakers entrusted with managing the various cross-sectional difficulties related to the energy progress. To that end, educational programs have the power to engage communities to educate them on the benefits of technology and the impact of their choices as "energy consumers".

Related work

Pietrapertosa et al. [11] describe an educational awareness program to reduce energy consumption in 4 schools managed by the Municipality of Potenza in Italy. The Schools4energy methodology focused on promoting sustainable behaviors in students under the age of 14 as a competition amongst schools while including artistic activities and games. The competition called "School Race" aimed to drive schools to reduce energy consumption by adopting good sustainable practices, the "Art4Energy" focused on creating artistic energy concepts which were shared on social media to generate awareness and to vote on the best works, finally the "Play4Energy" focused on using video games with energy themes available from other European projects. The results show a 4% decrease in natural gas consumption and a 0.5-4.3% per capita increase in electric consumption producing savings of about €1122.

Another similar approach to generate energy awareness through gamification (use of game playing elements to encourage engagement with product or service) in European schools is The GAIA Project [12]. This project focuses on an Internet of Things (IoT) approach to monitor the energy consumption of the schools while also monitoring key parameters such as temperature and humidity. Students are able to build circuits while sensors and devices like Raspberry Pi monitor environmental variables. This program also includes a challenge that motivates students to engage in activities to save energy while also comparing the performance scores between different classes and schools.

Power Forward Program

The Power Forward Program was launched in summer 2020 with a focus on initially engaging students in Philadelphia and, through these students, eventually reaching the broader community. This new program will educate underserved communities in Philadelphia about energy choice, equity, and justice. This program is collaborative effort of Villanova University's College of Engineering (COE) and EarthShare to expand underserved communities' knowledge and understanding of renewable energy in Philadelphia and beyond.

The Power Forward Program employs a dynamic, community-based, sustainable network through the collaboration of university student mentors; institutional stakeholder managers; high school principals and teachers; high school students in the VESTED Program; and the family, friends, and acquaintances of high school students to reach as many participants as possible, with measurable outcomes. We believe that this strategy will lead to long-term change and a measurable increase in the awareness of and use of renewable energy among underserved communities.

Content for the Program

Students and faculty at Villanova University developed the Power Forward Program based on a highly interactive program of activities and lectures to teach high school teachers and students about various aspects of renewable energy. The curriculum includes basic electric circuits, energy production, transmission and distribution, energy efficiency, household energy use and environmental impacts and economics of different types of energy. Some of the innovations in this program include the development of energy-related puzzles and games. In addition to the students in the program, family members were invited to participate in the activities so that it became more of a family affair than simply a student only program.

Power Forward Program has held its first eight sessions covering the following topics:

1. Introduction to electricity
2. Energy generation, transmission, and distribution
3. Energy and electric circuits
4. Energy efficiency
5. Introduction to renewable energy
6. Fundamentals of Solar Electric Circuits
7. Economics of Renewable Energy & Career Path in Renewable Energy
8. Social, Environmental, and Political considerations for Renewable Energy Systems

Several materials have been sent to the students including: an electric circuits kit, solar cells, a digital multimeter, energy-efficient bulbs, and an energy monitoring device. The content presented during the workshops followed the best practices for energy education including content from the US Energy Information Administration[13], US Department of Energy[14], and the National Energy Education Development Project [15]. While the students enjoyed learning about new topics in the area of electrical engineering and renewable energy, the feedback provided by the students indicates that the interactive activities, experiments, and puzzles were the most helpful and entertaining to perform and learn. An example of a assembling a basic electric circuit activity is shown in Fig. 3.

Figure 3: Facilitators and students working on building a simple electric circuit during the Power Forward program.

In addition to increasing knowledge of renewable energy, the Power Forward Program provided opportunities for students to learn about careers related to renewable energy. In the seventh session of the program, we had the opportunity to feature speakers from the Regional Transmission Operator PJM as well as a Solar Industry expert. During these sessions, students were inspired to follow their passion while learning what are the steps to follow a career in the renewable energy sector.

Furthermore, during the eighth and last session of the workshop, we had the opportunity to host guest speakers from NRG and the US Department of Energy's Department of Electricity who spoke on the topic of Energy Policy and Energy Justice, respectively. Likewise, the students were very interested in learning about the different considerations and impacts of electricity and renewable energy. In this last session, the students were awarded certificates of participation and completion of the Power Forward Program.

Challenges from COVID-19

Though the pandemic presents immense challenges, the Power Forward Program proves resilient and the model was adapted to meet the realities of social distancing requirements. While we planned to deliver in-person workshops for students and the community, we transitioned to virtual workshop formats on Zoom for the students. The COVID-19 pandemic created obstacles for recruiting students and engaging the broader community; however, we are pleased to report that we recruited 10 high school students and two high school teachers to the program from five schools in Philadelphia. The workshops were as interactive as possible, with the students engaging in activities, experiments, hands-on guided demonstrations, and games that reinforce the concepts of energy usage, choice, and impact. The long-term plan is to have in-person workshops when possible and eventually expand these workshops to the broader community.

Monitoring and Evaluation

The Power Forward Program developed assessment materials to measure the impact of the program on students and whether it increases their knowledge of and interest in renewable energy and related concepts. The assessment included two surveys that were administered to the students before and after the first and last workshops respectively. Outcomes-based assessments will enable us to improve the workshops moving forward and ensure that the program achieves its maximum possible impact.

Pre-workshop Assessment

The results of the survey before the start of the program showed that 71% of the students understood the difference between renewable and non-renewable energy. The students also agreed that there are many job opportunities in the renewable energy field and that they would likely recommend a friend or family member to use renewable energy systems.

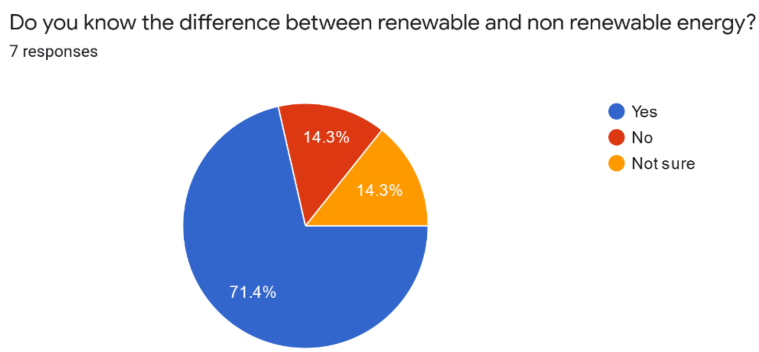

Figure 4: Data showing student responses the question about understanding the difference between renewable and non renewable energy.

An interesting response showed that 43% of the students remained neutral to the statement that “each one of us is responsible for reducing climate change”. This was further confirmed by their answers to their awareness of the impact of different behaviors such as turning off appliances when not using them, using energy-efficient lightbulbs, and buying renewable energy from your electricity provider.

Given the responses from the survey, a higher priority for the workshops was to include interactive activities and highlight different contributions that they can make in their homes to promote energy savings and save money on their electric bills while also learning about different renewable energy sources.

Post-Workshop Assessment

In the post-workshop assessment, 100% of the students rated the program with 5/5. “Being able to create our own circuits from home”, as well as the “interactive” activities and conversations about “real-life examples” were the main comments on what they liked more about the program. In terms of feedback to improve a student mentioned that sometimes the slides “felt repetitive” for particular topics. Also, “more student discussion” was suggested to get a chance to know the other students in the program. Finally, some scheduling constraints were also mentioned which were

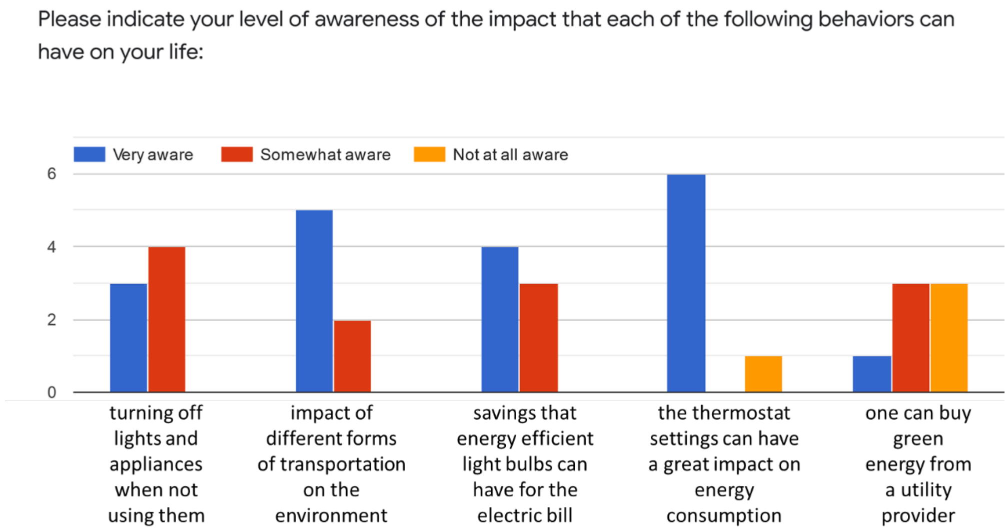

Figure 5: Data showing student responses to their awareness of the impact that different every day activities have on their energy bills.

solved for the most part by posting the video of the workshop online. Taking into account the challenges in preparing and delivering the workshops remotely during the COVID-19 pandemic, these suggestions will be considered for future programs. Overall, the students agreed that printed materials, videos, and hands-on activities were the most effective during the program.

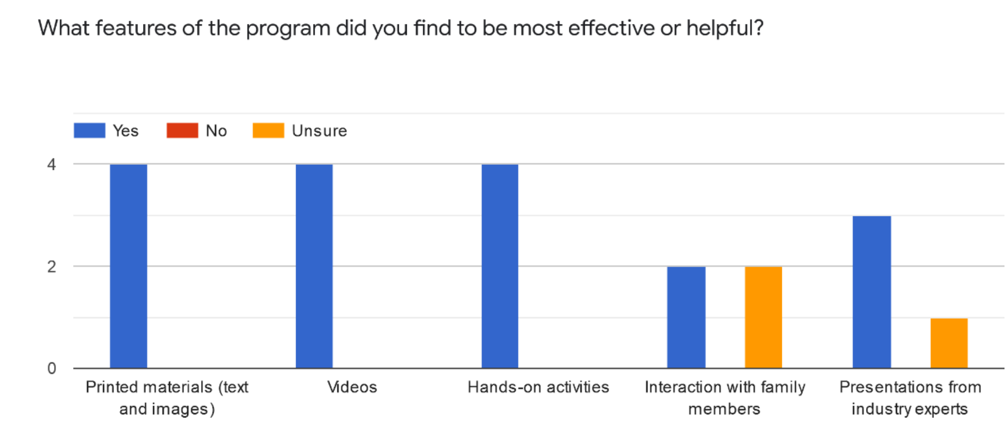

Figure 6: Data showing student responses on the effectiveness of the program.

After completing the program, students became more aware of different contributions that could make to reduce their energy consumption at home including an energy audit, making sure they have energy-saving light bulbs, checking thermostat settings, and turning off appliances at home. The results of the survey show an increase in awareness of different activities or behaviors compared to the first survey.

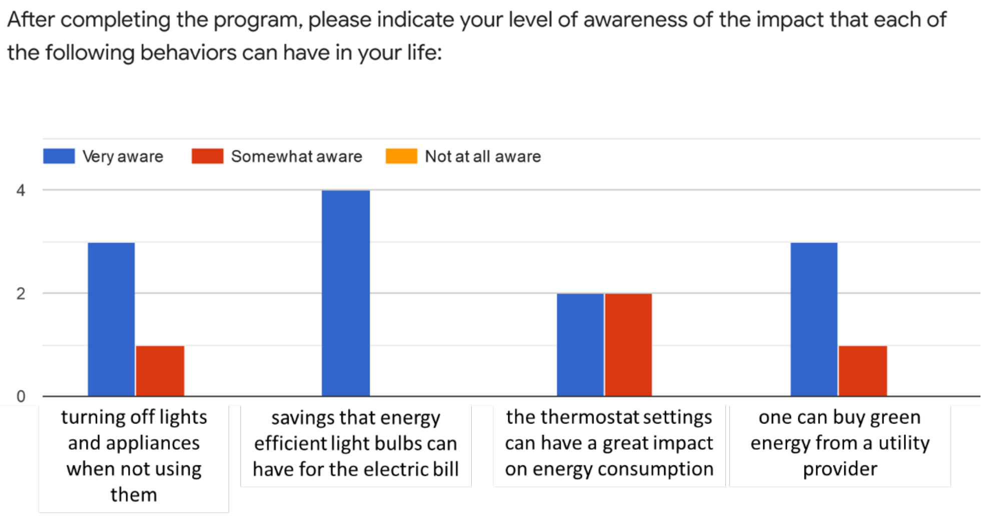

Figure 7: Data showing how their awareness towards different behaviors affect their electric bills at the end of the program.

Finally, students continue to agree that they would likely recommend their friends and family to use renewable energy systems. Furthermore, 50% of the students were very likely considering a career in renewable energy or the power industry while the remaining 50% is neutral about this. The results of the surveys show the impact of the program on students increasing their knowledge of and interest in renewable energy and related concepts.

Lessons Learned

Similar to every online interaction or Zoom meeting we have come accustomed to currently, we established key guidelines for how to prepare your background area to be able to engage and participate in the program. General guidelines included looking for a quiet area, taking care nothing is distracting in the background. Given the online nature of the program, it was also important to have a working webcam and microphone to engage with facilitators as well as the other students.

It was key for the program to provide the students with a kit for experiments including basic electronic components such as breadboards, resistors, switches, LEDs, and basic electrical components such as solar cells, multimeter, DC motors, batteries, and LED light bulbs. Delivering these components beforehand allowed for a more seamless experience to complete the activities required in each session. The students were excited to be performing experiments with the lab kits. It's worth noting that its challenge was to troubleshoot the circuit when it was not working properly. The instructors used the webcam to point to the circuit as it was being assembled and students did the same to troubleshoot basic circuits.

Another useful practice during a remote program was to record the sessions and provide the link to all the students so they can watch the session again at their own pace, or watch it for the first time if they were not able to attend the live session. This allowed some flexibility for students to complete all the activities. It was also very helpful to develop personalized how-to videos on YouTube so students can review the video and learn skills such as using a breadboard or a multimeter. An example of such a video is shown in Fig. 8.

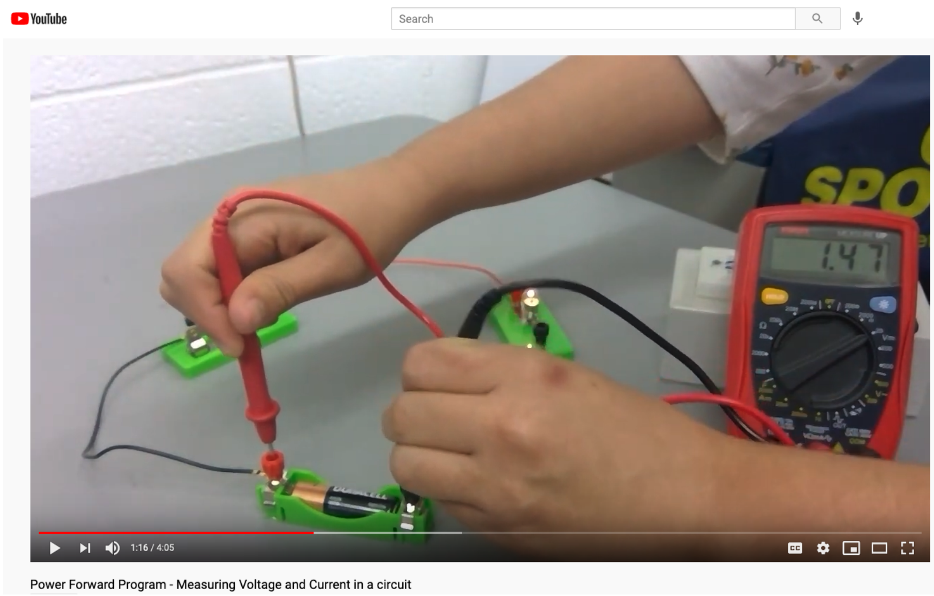

Figure 8: Example of video developed for the program describing how to use the multimeter to measure voltage and current.

While there were many diverse activities to generate interest in electrical engineering and renewable energy such as watching a movie, performing an energy audit, having industry exports guest lectures, and a series of puzzles and activities, there were many activities that could have been developed over time such as changing light bulbs from incandescent to LED and checking how energy bill cost improves over a period of several months.

It was a challenge to keep students engaged and motivated. One of the drawbacks was that students would not turn in the assignments for the program. To address this issue, facilitators were in contact with students to remind them to turn in the activities. Also, while the students interacted with their parents in some of the take-home activities, their family members were not actively involved with the program during the live sessions.

Future programs should prioritize activities and assignments that generate more interaction between the students and not just with the facilitators. One option would be to recruit more students from the same school to have them interact with each other and with other students. Besides, we can encourage participants to engage in discussions about career choices and professional journeys with facilitators to promote STEM and careers in the power and renewable energy sectors.

Future Work

Villanova University is excited by the opportunity to reach underserved communities in Philadelphia and is eager to strengthen our partnership with EarthShare. We seek to further opportunities to disseminate and share the materials we are developing with other organizations engaged in similar work and translate materials into Spanish to reach LatinX communities.

We also are eager to share lessons learned and best practices for community engagement with other organizations in EarthShare's network. As mentioned in the proposal, Philadelphia has the highest poverty rate among the largest 10 cities in the country. This offers challenges and opportunities to educate and excite residents in underserved communities about renewable energy's potential to positively impact their communities. Villanova University's College of Engineering is a national leader in sustainable engineering and views the Power Forward Program as an opportunity to use our expertise in this area to have a positive impact on low-income residents of Philadelphia. We appreciate EarthShare's support and look forward to expanding our partnership.

Acknowledgments

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