AC 2012-5491: VOICES OF IMPACT FROM THE PUBLIC (VIP): AN ETHICAL PERSPECTIVE

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Sylvia Wilson Thomas is currently an Assistant Professor in electrical engineering at USF in Tampa, Fla. She has more than 20 years of industrial and academic experience, assisting in the success of such companies and organizations as Bell Labs/Lucent Technologies, advancing analog/backend technology, Kimberly Clark Corporation process engineering, IBM, Procter & Gamble, the National GEM Consortium, and ITT Technical Institute. Thomas leads the Advanced Materials Bio & Integration Research (AMBIR) group at USF. Her research motivation is focused on the characterization and development of novel materials for biomedical/biological applications and energy integration. Projects in her laboratory include thin film and nanofiber material growth and characterization for biocompatible RF and energy harvesting devices; nanolaminated materials for thermal energy storage; and nanofiber filters, sensors, and channels. Currently, she is advising four undergraduates, two M.S. students, and five Ph.D. students. Her expertise/laboratory capabilities include chemical vapor deposition (CVD); atomic layer deposition (ALD); electrospinning; material/film characterization: AFM, XRD, SEM, TEM, C-V measurements, and FTIR; and device fabrication: sensors, capacitors, inductors, filters, and detectors, working at the Nanotechnology Research and Education Center (NREC) facility, http://www.nnrc.usf.edu/. Thomas holds B.S. and M.S. degrees in electrical engineering from Vanderbilt University, where she was a Patricia Roberts Harris Fellow. Thomas received her Ph.D. in electrical engineering from Howard University, as a NSF Materials Research Center of Excellence Fellow. Thomas was a National Science Foundation (NSF) Research Engineer in Korea at Chonbuk National University. She holds two patents in microelectronics processing for thick metal inductors and encapsulation and has recently filed three new disclosures in the application of advanced materials for bio and sustainable energy technologies. She has received more than $1.5 million in NSF funding and is the lead Principal Investigator, PI/Co-PI, on three Research Experience for Undergraduate (REU) program grants, focused on advanced materials, sustainable energy, and sustainable environments, respectively. Thomas is also the USF GEM Consortium Representative and an Alfred P. Sloan Foundation Minority Ph.D. Mentor.

Voices of Impact from the Public (The VIP Report): An Ethical Perspective

I. Background

The National Institute for Engineering Ethics consistently looks at ethics cases to determine and support policies for emerging technology. In the case of nanotechnology, the public awareness and activism has been notably low concerning this area and nanomaterials. As new nano innovations have moved from the research lab to market, the general public has experienced the impact of this technology, without really understanding or comprehending the social, environmental, or economical advantages or disadvantages.

A 2009 national survey by the Woodrow Wilson International Center for Scholars (WWICS) on Emerging Nanotechnologies indicated that Americans' awareness of nanotechnology is still low. In its national survey conducted for WWICS, the Hart Association found that the US public opinion on nanotechnology had increased only slightly to 68%.[1] With the nanotechnology industry manufacturing over $50 billion in goods, it would be beneficial for the general public to know about some of the new and emerging nanotechnologies. Similarly, a 2010 Research America survey on Floridians found that 60% of individuals in Florida would like to see more information about science and research.[2] Therefore, this work looks to assist in increasing the public awareness of innovative nanotechnology.

Particularly, the advancements in the area of nano materials technology, and its applications to alternative energy, have spurred the debate on ethical considerations for society and the environment. Dr. William Marcy, P.E., executive director of the Murdough Center for Engineering Professionalism at Texas Tech University, says "Engineers have a special role to play with regard to the ethical development of renewable energy technology and associated public policies".[3] Undergraduate student researchers at the University of South Florida (USF) took on this task and wanted to explore the ethical considerations surrounding their renewable energy research.

Students were eager to gain a clear understanding of their research endeavors and to express the research in layman terms to present an overview of their work to family, friends, peer researchers and colleagues, graduate students, faculty, and staff at universities. This small segment of the population gave us a snapshot of what the general public maybe thinking about research for sustainable energy solutions. In addition, this work presents an informative view, for the general public, into the laboratories of undergraduate researchers.

II. Introduction

This work focuses on addressing two concerns: 1) general public awareness of innovative nanotechnology research and 2) ethical aspects of nanotechnology in the context of understanding public opinion. The research topic is centered around sustainable energy, nanomaterials, and nanotechnology applications to energy alternatives, which is relevant to the

author's research area. As the Principal Investigator for the National Science Foundation Sustainable Energy Alternatives and Advanced Materials (SEAM) research experience for undergraduates (REU) program, the author, in collaboration with faculty mentors, has set one of the objectives of the SEAM REU as 'building a pool of ethically responsible researchers who are poised for technical competitiveness'.

As part of the SEAM REU site, students are engaged in breakfast journal club discussions, readings, industry field trips, and seminars based on the ethical and societal impacts of their research. The overall impacts of the students' ethical discoveries and acknowledgements have been captured in this article entitled "Voices of Impact from the Public (The VIP Report): An Ethical Perspective". In this first volume of the VIP Report, we discuss the results of certain students' interviews with peers, friends, and family, on how aspects of their research will affect the general public and the environment. The specific areas addressed in this article are 1) Nanotechnology in Solar Cell Development, 2) Nanotechnology in Electronics, 3) Nanotechnology in BioEnergy, and 4) Nanotechnology and Fuel Cells.

III. Methodology

As utilized by anthropologists, sociologists, and psychologists, this work has employed a combination of techniques, "survey research design" and "convenience sampling".[4,5] With the summer research program having a duration of ten weeks and limited funding, these two methods were deemed appropriate to address the two concerns of this work. Particularly, survey research designs are very valuable tools for assessing opinions and trends, even on a small scale. Survey research designs can capture impactful representations of small samples, and it is understood that the design must be very well prepared. The design must be transparent, assessable and easy to critic to avoid biasing and obtain accurate opinion representation.

As with most cases, sampling of an entire population is expensive and timely, and for this reason most researchers chose the most common method of sampling, convenience sampling. Convenience sampling was well suited for the ten week REU program and served as a pilot survey for future work in this area. It should be noted that a disadvantage for using convenience sampling is systematic biasing that may occur due to difference of opinions between the sample and the entire population. This work will obtain opinions more specific to the sample population and not make overall generalization for the entire population. The sample population was determined by the REU students and their access to individuals in their immediate circle (peers, graduate student colleagues, faculty, staff) and those with valued influence on their lives (family, faculty, mentors). The sample size ranged from as large as 40 to as small as 17. The smaller sample size was restricted by the REU student to individuals with an engineering and science background, as these individuals are "expected to be the catalysts for change and improvement". A post evaluation of the sample size was conducted using the Sample Size Calculator developed by Creative Research Systems. The Sample Size Calculator allows the research to assign a 95% or 99% confidence level and select a confidence interval (error margin).[6]

The formula used to determine sample size is

$$ss = \frac{Z^2 * (p) * (1-p)}{c^2}$$

Where:

Z = Z value (e.g. 1.96 for 95% confidence level)
p = percentage picking a choice, expressed as decimal
(.5 used for sample size needed)
c = confidence interval, expressed as decimal
(c= 05 or ±5 standard deviation was used for this work)

For all of the surveys conducted in this work, there was a finite population assigned and the finite sample size is determined by

$$\text{new ss} = \frac{ss}{1 + \frac{ss-1}{pop}}$$

Sample sizes were verified and assessed by the PI and all seemed appropriate for this work.

In an effort to facilitate 1) the design of a well prepared research survey and 2) sample and unbiased population, the following activities were completed:

- Students conducted literature reviews of each nanotechnology topic (prior to program start)
- Students received training in expressing technical research in layman terms
- Students reviewed previous ethical case studies to bench mark appropriate questions
- Students worked with graduate student and faculty mentors to develop survey questions
- Students used email, monkey survey, facebook, and face-to-face to administer survey

Survey questions referred back to the two concerns and research aim of gathering a perspective on nanotechnology from the general public. These qualitative data provided the REU student researcher a glimpse of public opinion and this process served as one ethics training module for the students.

IV. Areas of Nanotechnology Addressed

The novel and innovative approach to gathering this public opinion data began in the 5th week of the REU program when students attended a writing workshop on "How to convey

scientific research to the general public", conducted by USF professor Mark Walters, author of "Communication Skills for Medical Professionals". [7] The following is a summary of the findings of this work.

A. Nanotechnology in Solar Cell Development

1. Public View for the "Investigation of Al / MEH-PPV Interface Using Electrospray in High Vacuum", Kathleen Baumback, Rudy Schlaf

Solar cell panels are an intense area of research for their many potential advantages. The ability to harness the infinite energy of the sun would solve troubling, controversial problems such as using up finite resources and putting an end to our carbon footprint. If enough efficient solar cells were placed around the world, solar energy could be used to power our homes, cars, and personal devices, with plenty of energy to spare.

Obviously, this idealistic situation is some time off. Scientists still need to work around problems such as storing energy when the sun isn't shining; extend the lifespan of solar cells; figure out what to do when the product's lifetime ends; and, of course, make the technology affordable and available to be produced on a large scale. Fossil fuels are still far cheaper to use overall than solar cells. Solar cells can be fairly expensive to create; their total price depends on the method of fabrication and the materials used.

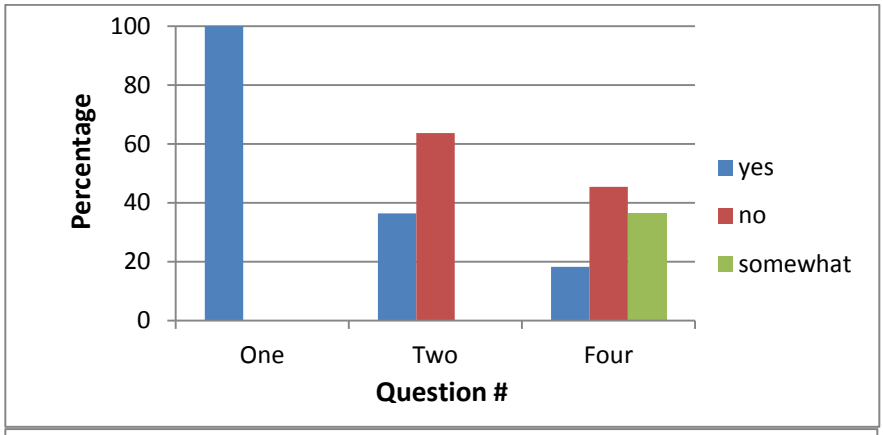
Silicon is currently the most popular material for photovoltaic devices because of its ideal electronic properties. Crystalline silicon solar cells are the most power efficient — however, quality silicon can be fairly expensive to obtain. The cheaper, slightly less-efficient competitor of the silicon solar cell is the thin-film solar cell. Thin-film cells are far more flexible than the unyielding silicon cell. However, some thin films, such as those made with cadmium, are potentially toxic; manufacturers compensate for this disadvantage by offering to trade back these cells at the end of their lifetime. Currently, the most popular material for thin-film solar cells is the indium tin-oxide dye-sensitized film; it produces the highest-efficiency solar cells in this category.[8-13]

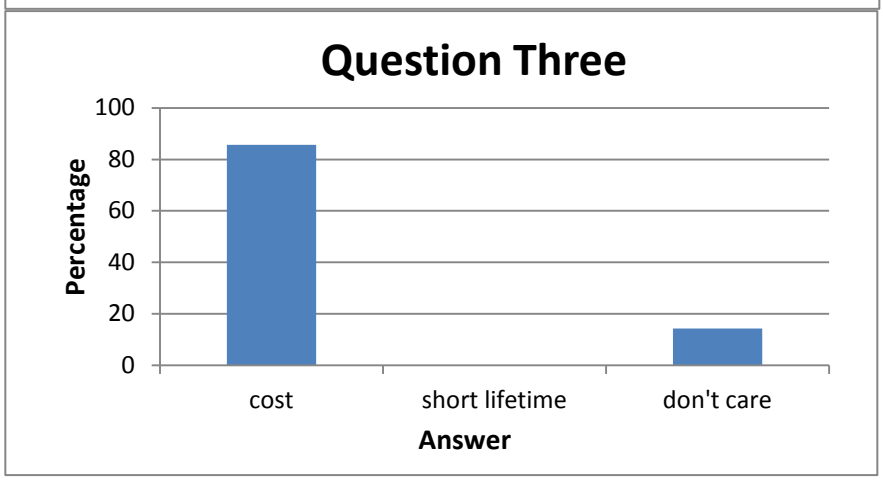
Unfortunately, indium may soon be very difficult to obtain in America. China accounts for 75% of the world's indium and has recently made the decision to discontinue exporting this resource. This means (in America at least) that the large-scale production of indium tin oxide solar cells may be either too expensive or physically impossible in the future. The answer may lie in the development of organic polymers. What is your opinion regarding this topic? Let's look at opinions from the following survey questions proposed to the general population.

1. Are you concerned about finding and/or utilizing alternate sources of energy in the near future?
2. Solar panels are available in stores today. Have you bought a solar panel for your home, or do you intend to buy one?
3. If you answered no to the above, why not?
4. Are you aware of the advantages of organic semiconductor devices over inorganic ones?

According to the results, many people are indeed concerned about moving toward renewable alternate energy resources. However, over 60% of those people have not purchased a solar panel, nor do they have any intention of doing so. It is unsurprising to see that this is mostly because of the high price of solar cell panels, especially compared to other energy resources such as fossil fuels.

Again, perhaps the answer to this problem lies with the development of more cheaply-manufactured thin-film solar cells. The majority of people who answered this survey know at least a little bit about the potential advantages of organic solar cells, such as increased flexibility, lower manufacturing costs, and higher power efficiency.





2. Public View of “Optimizing the Fabrication of Dye Sensitized Solar Cells”, Shamara Collins, Chris Ferekides

Fossil fuels are used most abundantly for supplying energy to our nation. Included in these fuels are: gas, coal, and oil. Since the Industrial Revolution, these sources have been used as the main energy provider. This timeless tradition is very harmful for the environment. To produce energy from fossil fuels, a combustion process is undergone. During combustion, many pollutants are emitted to the environment. Amongst these pollutants are green house gases and carbon dioxide, both of these emissions are attributed to the recent change in climate and depleting the ozone layer.

Although the hazards are evident, fossil fuels are continuously used because they are relatively cheap and available. Hypothetically speaking, fossil fuels are less expensive than alternative energy. However, when discussing these types of fuels, one must go beyond selling price. For example, $3.50 tank of gas may seem reasonable, but one must consider the effects of using the gas. When burning gas from your vehicle, many pollutants are sent to the environment. These emissions change the quality of air. Poor air quality has been associated with many public health concerns, including asthma and other lung diseases. Therefore, when discussing the expense of fossil fuels, the "real cost" should be taken into consideration. Continuing with the example of gasoline, the initial cost may only be merely a few dollars; it does include the price which the innocent public may pay for medical treatment after inhaling the cars exhaust. Availability of these fossil fuels is also something which needs to be taken into consideration. These fuels are predicted to run out within the next 50 years.[14] Not only is the combustion of these nonrenewable energies harmful, but also the way in which they are harvested. Procedures such as deep sea oil drilling have proven time and time again to be unreliable and devastating to marine life. This is extremely damaging, because not only are aquatic organism harmed but also the individuals which profit from the sale of seafood.

The cons associated with fossil fuel combustion should outweigh heavily against the upfront pay offs. Since fossil fuels are losing their popularity, an alternative energy is extremely necessary. A viable alternative is the use of renewable energy. More specifically speaking, solar power should be considered, because the Sun supplies Earth with $3.2*10^{24}$ joules of energy, yearly. To capture this abundant and everlasting energy source, 0.1% of the Earth's surface needs to be covered with solar panels that are 10% efficient.[15] There are many types of solar cells, but dye sensitized solar cells are most attractive because they are relatively cheap and environmentally friendly. Dye sensitized solar cells, mimic the photosynthesis process of plants when harvesting sunlight and converting it into energy for daily use. They replace the typical phase in contact with the semiconductor by an electrolyte, in return forming a photo-electrochemical device. Their fabrication process is cheaper, eliminating the need for expensive and energy-intensive high-temperature and high-vacuum processes needed for the other traditional devices.[16] Although the silicon solar panels are proven efficient, they do not degrade well in the environment. Also, the dye sensitized solar cells applications are endless. They can be used on flexible substrates, in architecture and are aesthetically pleasing.[17-28]

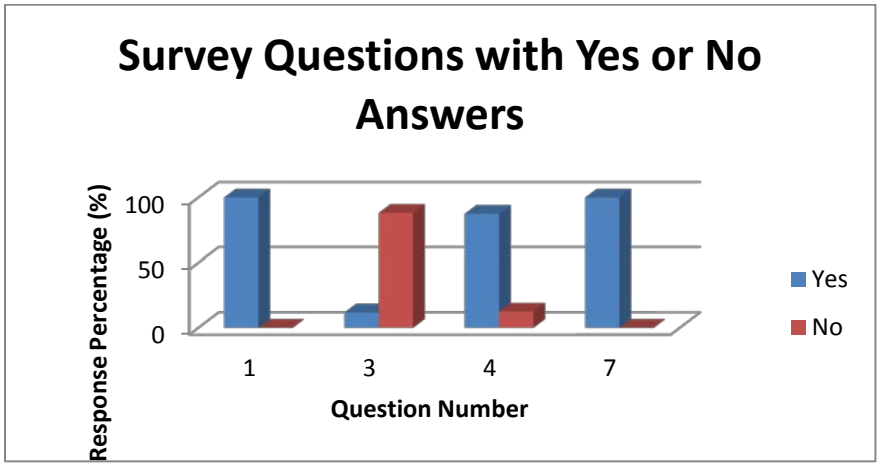
The purpose of this research project is to develop an optimized procedure for fabricating dye sensitized solar cells. It is important to create cells, which are efficient to help combat the current energy crisis. Energy is essential to maintain the quality of life our nation expects. However, our use of energy should not go without the consideration of its public health and environmental impact. Therefore, a cleaner zero-emissions energy source is necessary. It is obtainable through the use of solar power and specifically dye sensitized solar cells for the reasons mentioned above. What is your opinion regarding this topic? Let's look at opinions from the following survey questions proposed to the general population.

1. Do you have a background in engineering or science?
2. Do you understand the real cost for using fossil fuels?

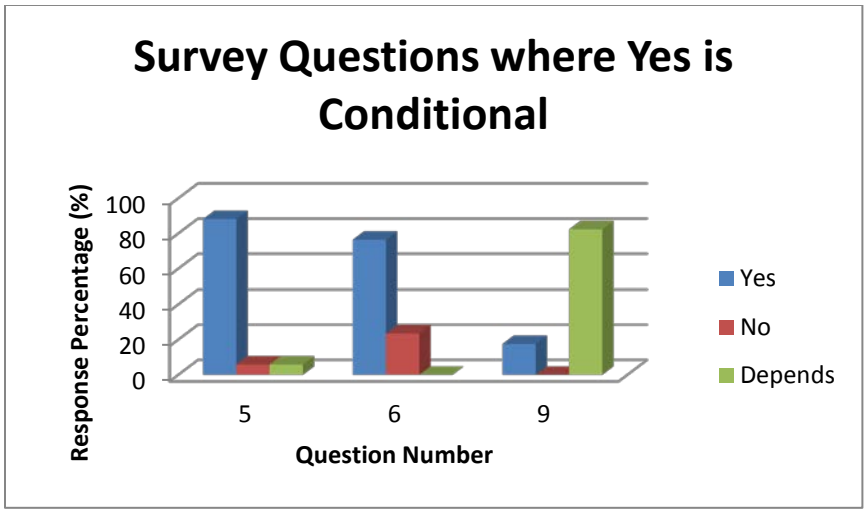
3. Would you live near a nuclear power plant or coal factory?
4. Do you feel morally responsible for the future of our earth?
5. Are you willing to live a sustainable lifestyle?
6. Did you know the Sun supplies Earth with 10,000 times the amount of energy the globe consumes annually?
7. Do you understand that photosynthesis converts light into energy for plants to use?
8. Have you ever heard of dye sensitized solar cells?
9. Would you use solar power within your own home?

The responses to the ethics survey give insight into how people feel about alternative energy and the current use of fossil fuels. The total sample size included 17 people all with engineering or science backgrounds. Considering people of the STEM profession are expected to be the catalyst for change and improvement, it is quite interesting to see their thoughts on our daily environmental impact with the use of fossil fuels.

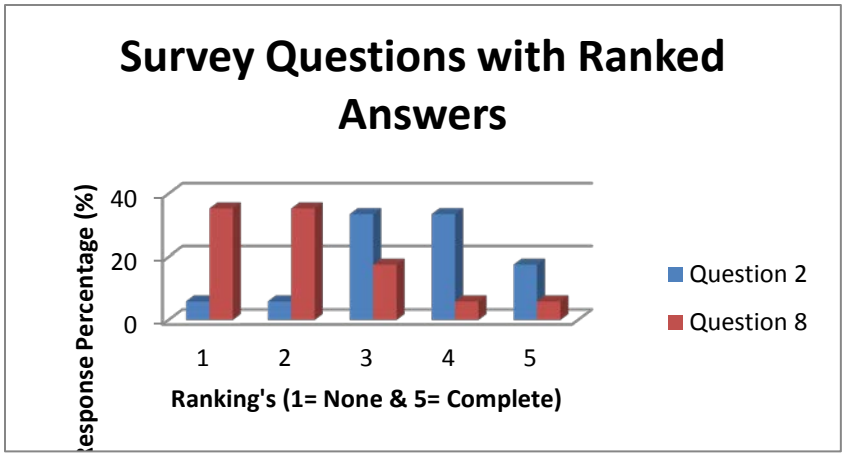
The survey's second question generates the most pertinent information. The question read, "Do you understand the real cost of using fossil fuels?" The real costs deals with more than the initial selling price, but also the cost of health care and other factors. As seen in Chart 3, a majority of the participants responded between 3 and 5, meaning they had a good understanding of environmental and public health impacts associated with the use of fossil fuels. Also, the responses to question number 4 shown in Chart 1 indicate that a majority of the sample population do feel responsible for the Earth.



[Chart 1]



[Chart 2]



[Chart 3]

Considering this, analysis of questions 5 and 9 are important. To live sustainably, one will reduce their consumption, recycle more and pollute less. In living such a lifestyle, one can reduce the negative impacts on the environment thus, taking care or responsibility for the Earth. 88.2% of the survey population responded that they would live sustainably. One person did not understand what the term meant and the other simply said "No". The one surveyor who would be unwilling to live sustainably also did not feel responsible for the future of the Earth, so at least they were consistent. But their opinion is alarming, because more people may feel the same. The opinion of this one surveyor could possibly represent many more within our nation, thus the reason why fossil fuels are still used in such abundance. To counter such thinking, the masses really need to be taught about fossil fuels negative impacts and the practicality of alternative energy. Also, question 9 asks how many people are willing to use solar power within their own homes. 17.6% of the sample population was willing to do so regardless of cost while 82.4% would use solar power depending upon cost. It is reassuring that all the survey participants are willing to use alternative energy, but again the dependence upon upfront cost is a major factor.

The questions that dealt with knowledge about solar power had some confident responses. Many knew about the Suns ability to supply the Earth with energy. Also, 100% of the responses to question 7 proved that people do understand that sunlight can be converted into energy for daily use. However, not everyone knew about the dye sensitized solar cells, which mimic the process of photosynthesis for solar devices to be used by humans.

To conclude, the ethics survey results proves that many engineers and scientist are aware of the detrimental effects of fossil fuels. Most of them believe in the Sun's ability to provide energy and some are even willing to use devices to harness this power. It is obvious that more education on the topic of solar power is needed. If engineers who are the catalyst for change need more information regarding alternative energy, it is evident that the general public does also. Research such as this project on dye sensitized solar cells, is a vital step into educating everyone about the potential of solar power and must continue!

B. Nanotechnology in Electronics

1. Public View of "Graphene-Polyanilase Electrodes in Super Capacitors", Nagid Brown, Ashok Kumar

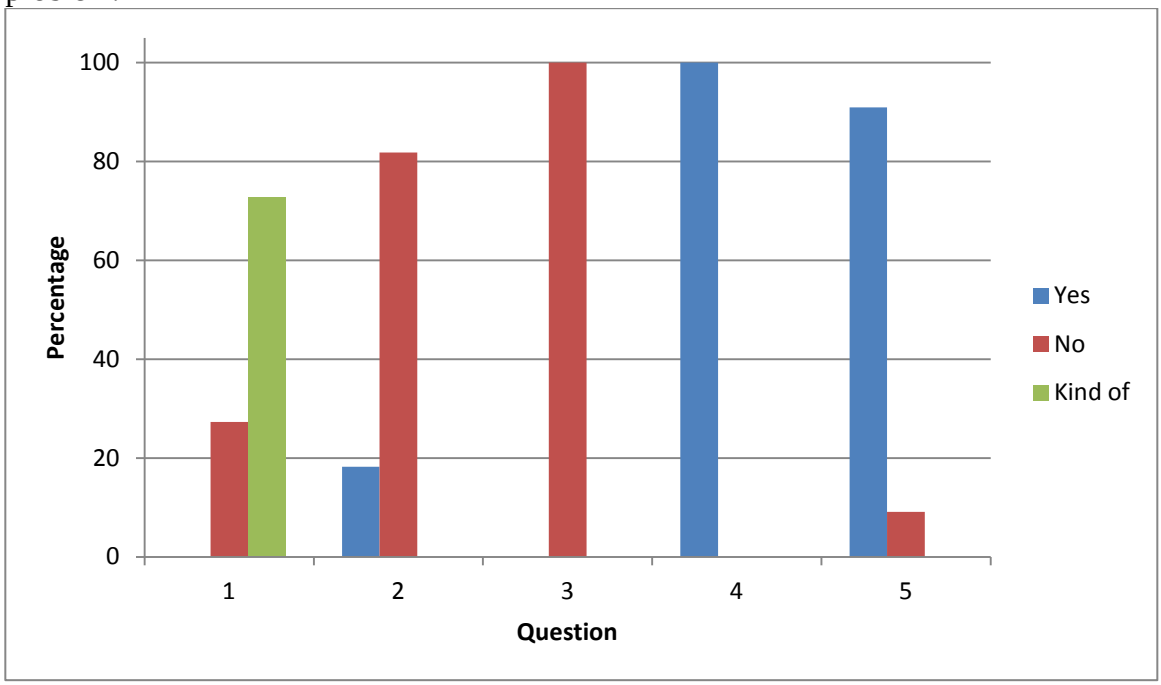
A super capacitor is an electrochemical device that turns chemical energy into electrical energy in the electrical double layer, which forms at the interface between an electrolytic solution and electrodes. They're composed of two electrodes, usually the same material, separated by an electrolytic solution. A positive charge is built up on one of the electrodes while a negative charge is on the other. An electric field is then created by potential difference between the electrodes. This electric field is what stores the energy to be expelled. Their primary purpose is memory storage, but now they have new application opportunities in portable electronic devices and maintaining power quality. Super capacitors can act as a back-up battery in the event of a power loss. It can also act somewhat like a surge protector regulating the flow of electricity to the battery.[29-31]

Super capacitors are so useful in electrical devices that they're even used in solar panels, but the electrodes in super capacitors are typically made of activated carbons which are harmful to the environment once expended. My research focuses on determining if graphene-polyaniline (G-PANI) is a viable substitute for the activated carbon used as electrodes in super capacitors. Development of the resources that we have and know don't cause damage to our environment is the only way to slow the degradation of our environment. What is your opinion regarding this topic? Let's look at opinions from the following survey questions proposed to the general population.

1. Do you know what a supercapacitor is?
2. Did you know that supercapacitors are used in almost all electronics?
3. Did you know that the supercapacitors used in solar panels and electric cars are composed of activated carbon that is both expensive and harmful to the environment once expended?
4. Would you support the production of a cheaper and environmentally friendly supercapacitor?

5. Would you approve the use of tax money in the development of “greener” supercapacitors?

Looking at the results of the ethics survey shown above provided some useful insight into how unaware people are of the effects of the items they use every day. They also show how willing people are to bring about change for the good of our environment once they know that something is wrong. I think that environmental organizations should make it their business to inform the public on environmental hazardous items used in everyday life in a more mainstream manner, because once fully informed people will be more willing to support remediation of the problem.



2. Public View of “Fabrication of a Stretchable Conductor”, Cristian Cabra, Arash Takshi

Device scaling trend continues forward toward smaller and smaller devices, we begin to see areas and functions that microelectronics seems to do more harm than good. For example, there are applications that require electronics to be spread over larger areas (macro electronics) such as X-ray’s imagers and some solar panels. Because of the nature of microelectronics, these macro electronic devices become more difficult and cost- inefficient to build and operate. In this regard, a promising field called flexible (stretchable) electronics offers effective means to deal with integrating better microelectronics into large-area macro electronic devices.

Flexible electronics is a rapidly growing field with many applications ranging from displays all the way to parts in soft robots. In order for this technology to function probably reliable stretchable conductors with low resistivity are necessities, especially for large area devices. The resistance of an interconnection line determines the delay between interfacing connections. Extremely high resistances can result in larger delays in the device. This would be a major problem in display devices where signals would lag behind. Generally metals are used for these interconnection lines because of their high conductivity. The biggest

issue with using only metal though, is that any strain beyond 2% tends to crack the metal thus rendering it useless due to the cracks causing it lose its conductivity.

It has been shown that stretchable metal interconnections can be fabricated by applying a conductive rubber in between a conductive metal and the surface of an elastic material. Polydimethylsiloxane (PDMS) and silicone are two choices for elastic substrates while Gold or Copper can be used as the conductive metal. Each has their strengths and weaknesses, but since this is a fairly new and emerging field, there are not many funds being allocated for further research. The same can be said about conductive rubbers because this method for using conductive rubbers has not really been researched.[32,33]

The big ethical question is whether or not this new and emerging field is a viable project that deserves funding. I created a survey and asked people what their opinions were. What is your opinion regarding this topic? Let's look at opinions from the following survey questions proposed to the general population.

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1. Do you have a background in Electrical Engineering or Science?
2. After reading the background information. Do you feel like this an important topic?
3. Important enough to have money further invested into the field?
4. If you answered YES, would you prefer the research be publicly or privately funded?
5. If you answered NO, briefly give a reason as to why not?
6. Would you be all right with an Undergraduate student being funded to do this research or would you only allow Graduate students to conduct this research?

Looking at the results of the ethics survey shown above provided some useful insight into the knowledge and thinking of people with or without Electrical Engineering backgrounds. The responses to Questions 2, 3, and 4 are very telling of how people feel towards this emerging field. For question 2, 94.9% (37 out of 39 responses) of the people felt like it was an important topic, and out of those 37 people, 36 of them felt it was important enough to have money further invested into the field. Question 4 is where people began to differ. 33.3% of people felt that this research should be funded publicly while 66.7% would rather it be funded using private means. This to me means that people want money to be invested into further research as long as it doesn't come out of their pockets. There did not seem to be a bias for people with an Electrical Engineering or science background. As in there was no pattern for people with engineering backgrounds to want public or private funds. It seemed to be a very random result. Question 6 had very interesting results and seems to show who people would prefer doing this research. You were allowed to choose more then one answer for Question 6. The answer choices were: Undergraduate Student, Graduate Student, Undergraduate Student with a Graduate Mentor, or Graduate Student with a Faculty Adviser. The results showed a very clear pattern.

Undergraduates - 25.6%
Graduate Students - 53.8%
Undergraduate Students with Graduate Mentor – 82.1%
Graduate Student with a Faculty Adviser – 56.4%

This to me showed that the most people feel Graduate students have to be involved in some way or form in conducting this type of research. I find it interesting that the third choice

got an overwhelming response rate because that is more or less how the REU program works. With the results of this survey I feel like a lot of people would agree that this research is an important thing to fund. Where the funds come from is another question which could have many different answers that depend on situations. If everything is explained in an easy and logical way, I do not see any major obstacles in the way of continued spending in the fabrication of a stretchable conductor.

C. Nanotechnology in Bioenergy

1. Public View of "Ethical Issues Related to the Proposed Bioenergy Generation System", John Headley, Henry Cabra

There are many electrical devices that can be implanted into the human body to enhance the quality of life, such as a cardiac pacemaker or an artificial heart. Electrical devices cannot work without a source of power, such as a battery.

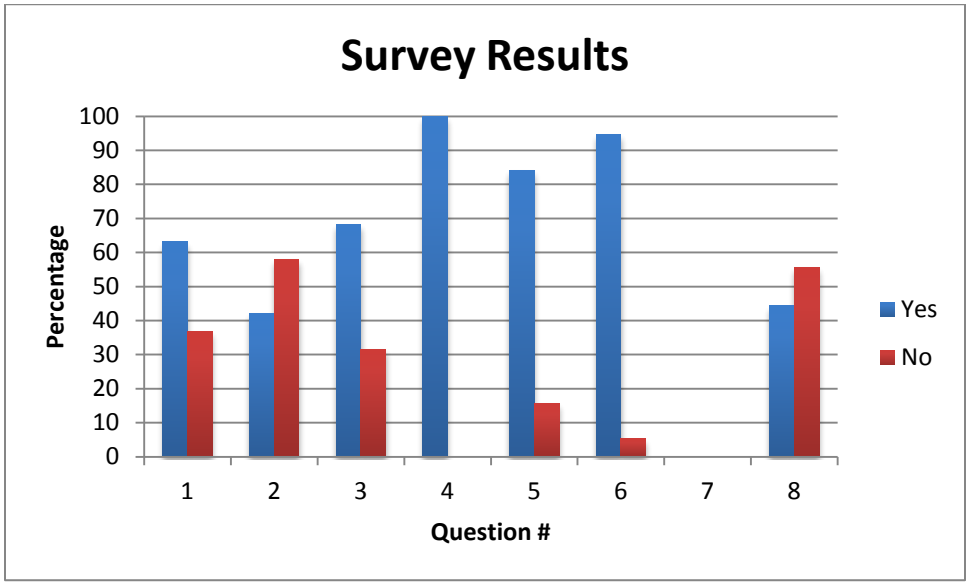
There are severally problems associated with a battery powered implantable device. The largest is that the battery does not last very long. The battery in a cardiac pacemaker typically only lasts between 5-7 years. At the end of the battery's life, the patient with the implant must have the battery surgically replaced. These repeated surgeries would seem to negatively affect the quality of a person's life. Surgeries are also very expensive, so not only would the patient have to have to be repeatedly operated on, there will also be repeated surgery costs. Even with insurance, money is being unnecessarily put into repeated surgeries. Another fact to take into consideration is that the battery contains materials toxic to the human body.[34-36]

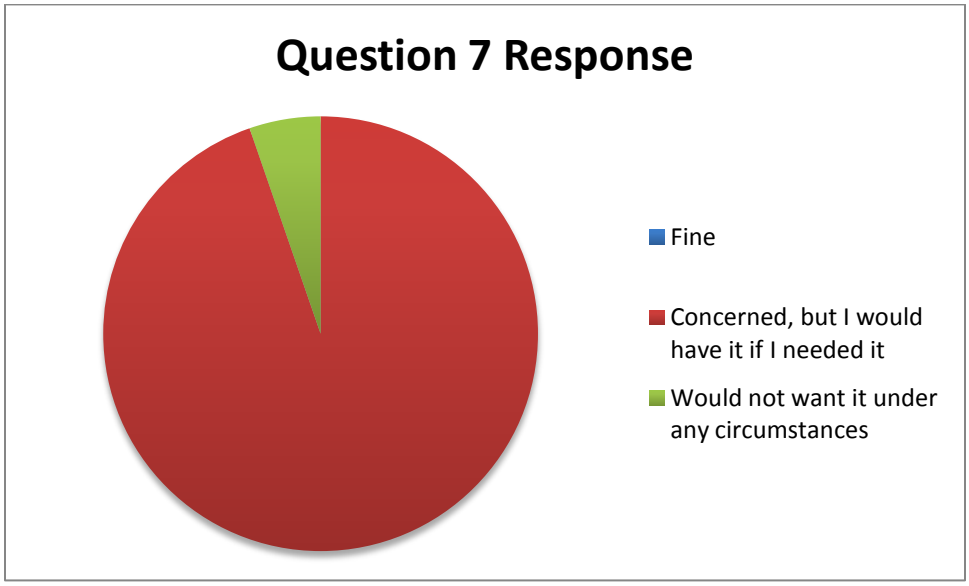
These problems are why our research efforts are towards developing an alternative or possible compliment to batteries in surgically implantable electrical devices. The research is towards a surgically implantable electric generator. There are ethical issues related to current implantable devices as well as more ethical issues created with our solution. What is your opinion regarding this topic? Let's look at opinions from the following survey questions proposed to the general population.

1. Do you have an engineering or science background?
2. Could you have guessed that 100,000 people have pacemakers installed every year?
3. Do you consider surgery to be unpleasant or invasive?
4. Do you consider surgery costly?
5. Were you aware that implantable electrical devices, such as a pacemaker, require a battery for power?
6. A typical pacemaker battery only lasts around 7 years and then has to be surgically replaced. Do you think repeated surgeries affect the quality of a person's life?
7. How would you feel about a pacemaker being implanted in your body?
8. Would your opinion change if the device was not a pacemaker, but instead another type of implantable electrical device?

The results are interesting. The majority, despite the educational background, were not educated on the subject of implantable devices, such as pacemakers, as we can see in question 2 and 5. However, once educated a little bit, they did agree with the cause for our research and provide solid ground for the importance of the research.

Questions 3, 4, and 6 showed that most people agreed that surgery was costly and repeated surgeries affected the quality of a person's life. The research group's implantable electric generator would make the implant more permanent, reducing the number of surgeries and surgery costs.





One important thing to mention is that the idea of surgically implantable devices is still uncomfortable to most people. Question 7 and 8 show that having a device surgically implanted in your body makes a person uneasy, despite what device it is. A life or death situation would surely influence a person's decision, but I think it would be best to educate the public more on these life altering devices, especially once this implantable generator is developed.

D. Nanotechnology and Fuel Cells

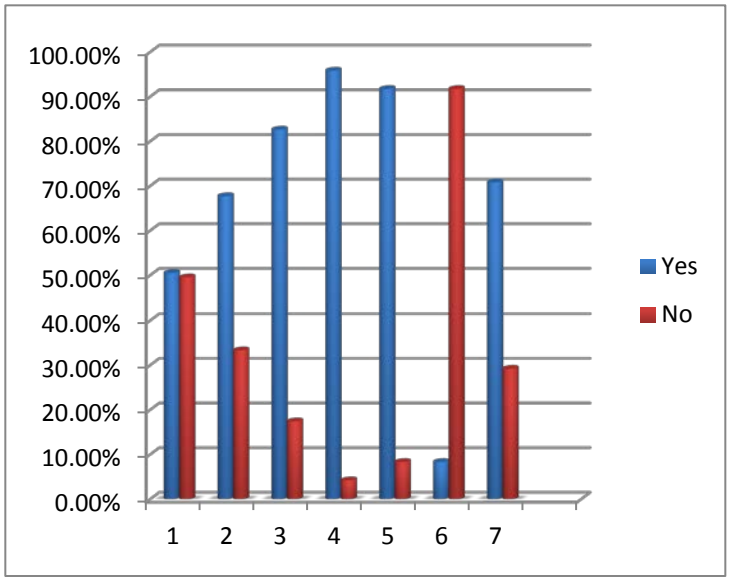
1. Public View of "The Benefits of Fuel Cell Technology", Kneath Warrington, John Kuhn

Fossil fuels have brought great advancement to mankind and were the driving force of the industrial revolution. However, the very thing that has brought so much development and joy to mankind is also destroying the world that we live in. Fossil fuels are one of the most dangerous threats to the environment due to the pollution caused in the atmosphere. The burning of fossil fuels greatly contributes to global warming, pollution of water and land and they contribute to acid rain. Huge amounts of carbon are released into the atmosphere when fossil fuels are burned and this contributes to the greenhouse gas effect, which causes the sun's heat to be trapped in the atmosphere. The trapped heat contributes to global warming, which we are experiencing today.

Alternative sources of energy are being researched and developed in order to combat this problem, however, most to the energy sources proposed such as wind, solar, geothermal, hydroelectric, etc. all have stationary applications. Fuel cells provide good option for providing energy to the nation's transportation industry because of their mobile applications. Fuel cells do not pollute as much as fossil fuels, they can be installed in neighborhoods where people live and they produce reusable heat, which makes them highly efficient.[37-40]

According to United States Environmental Protection Agency, only about 14%- 16% of the energy from fuel in the tank of an automobile gets used when driving. The remainder of the energy is lost to the environment, due to the high inefficiency of the combustion engines. Using fuel cells in cars would make them a lot more efficient and since the fuel cells produce reusable heat, the amount of energy lost will be greatly reduced. Therefore it is imperative that the development of fuel cells be given more attention than it is getting. What is your opinion regarding this topic? Let's look at opinions from the following survey questions proposed to the general population.

1. Do you have a background in science or engineering?
2. Do you know what fuel cells are?
3. Would you purchase a vehicle that utilizes fuel cell technology?
4. Do you think that fossil fuel is dangerous to the environment?
5. If cleaner and efficient energy sources were developed, would you support a petition to prevent the further burning of fossil fuel?
6. Would you live near an electric power plant that burns fossil fuel?
7. Would you authorize the spending of tax dollars to support the production of fuel cells on a large scale?



The y-axis represents the percentage while the x-axis represents the number of questions.

The results of the survey reveal useful information about the value that engineers, as well as non-engineers place on the environment around them. According to question 6, more than 90% of the people who took the survey answered that they would not live next to a power plant that burns fossil fuel. The result from Question 4 also indicates that people are well aware of the dangerous threat of fossil fuels. However, in some small communities where electricity only comes from fossil fuel power plants, the people have no choice since the power plant must be installed near the community.

More than 80% answered that they would purchase a vehicle that utilizes fuel cell technology, which is clear indication that if the technology were made available, people would be ready to transition. It is now up to the government and the policy makers to implement the right policies, to allow fuel cells technology to be properly researched and developed in order to become our main source of energy. As indicated in question 7, out of the 40 people who took the survey, more than 60 % would support a petition to ban fossil fuels if a better type of technology was developed.

V. *Conclusion*

The summarized results reveal the level of understanding the general public has about current research in the area of advanced material applications to sustainable energy alternatives such as solar technology, biomass fuels, fuel cell development, supercapacitors for energy storage, and more. Assessment of this process is done on several levels, such as faculty/graduate student review of abstract and survey questions, peer review of questions, and open weekly dialogue discussions regarding expected outcomes and format. The undergraduate researchers were impacted by the results they found and began to form different opinions themselves about the approach and methodology, and development of nanotechnology. Future public opinion will be conducted and submitted for publication in an effort to disseminate innovative research being conducted in nanotechnology.

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