**2012 STAR Program**

**Lesson Plan Cover Page**

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| **Lesson Plan Title: Working with Solar Cells** |
| **Research Project Title: Graphene Enhancement Study by High Temperature Anneals** |

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| **Lesson Plan Overview** | Working at NREL has motivated me to infuse my teaching style with information on energy consumption and renewable energy. I often feel that there is disconnect between city life and the environment. Working in Milwaukee will give me a great opportunity to help students become aware of what it takes to power their lifestyle. For my lesson plan I decided to focus on solar energy. I thought it would be an easy way for me to tie in my research as well as provide them with a lab that will get them thinking about renewable energies. They will be given solar cells and allowed to play with them for 10 minutes. I will have a light bulb, rechargeable battery, and LED. After this initial experience with the solar cells I will give a small lecture on solar cell technology. They will then receive a lab on solar cells that I found through a PhET forum. |

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| **Unique Research Connections** | In my time are NREL I became aware of the large amount of collaboration between different groups of scientists at various labs. On the team that I worked with, I was able to learn from material scientists, chemists, and physical chemists. I think it will be important for me to make my classroom aware of how research science never falls into one subject like chemistry or physics. My unique research connection to my lesson plan will come from the use of graphene to make solar cells more efficient. The lab will have the students try different color light and measure the output. By explaining to them how graphene has an flat absorption curve, they will hopefully see the benefit in PV. |

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| **Grade Level(s)/Subject** | 9-12  Physical Science, Physics, Chemistry |
| **Standards Addressed** | National Science Education Standards CSMEE  Science as Inquiry standards  Abilities necessary to do scientific inquiry  Understanding about scientific inquiry  Science in Personal and Social Perspectives  Natural resources  Environmental quality  Wisconsin State Standards:  D.12.11 Using the science themes\*, explain\* common occurrences in the physical world  H.12.3 Show how policy decisions in science depend on social values, ethics, beliefs, and time-frames as well as considerations of science and technology  G.12.5 Choose a specific problem in our society, identify alternative scientific or technological solutions to that problem and argue it merits |

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| **Materials List** | * 1. Small PV cells   2. Several sheets of colored transparency film in different colors   3. Two electrical leads with alligator clips   4. DC ammeter   5. DC volt meter   6. Sour of bright light or access to direct sunlight   7. Aluminum foil   8. Protractor |

Lesson Planning Template

Title of Lesson: Solar Energy and Energy Crisis

Grade Level: 9-12

Lesson Plan Preparation:

1. This lesson will require 1W 6V solar panels that can be purchased from RadioShack. They are a little pricey (around $7.99) so the size of groups might be determined by how large a budget. I know of stores like American Science Surplus that sometimes sell used solar cells so that might be a more appealing option. This lesson will assume 7 groups of three students each with five solar cells. To wire the solar cells I would recommend 12 AWG wire and alligator clips so that the system is better situated for reuse. Solder can be used at the end to make a more permanent device.

Description of Learners

1. This lesson plan would be intended for a high school level course in physical science or physics. Perhaps it could even be covered in a chemistry based class. Basic electrical principles would be required prior to the introduction of this class. Therefore I would not recommend the topic of photovoltaic as the starting point for a circuits unit.
2. The big ideas in this lesson would be construction of photovoltaic cells and their effect on the environment. I have decided to set up the lesson in two parts. The first section will be a sort of free for all where the students can set up the PV’s and play with them using various objects include with their kit. I want them to have an experience with the solar panels before I give them instruction. After this brief period of instruction, I then will hand them a lab report that they will complete in groups. A great way of connection new knowledge to prior knowledge is through a journal system. Asking just four questions about what the students might have learned, will learn, or opinions on a subject will go a long way in facilitating discussion.
3. What students should know prior to this lesson:

* Basic understanding of conductors and insulators
* How to set up a basic circuit
* Ideas central to the understanding of an electron
* How current works
* Parallel and Series circuits

1. It is always hard to guess what the misconceptions will be for a specific lesson. These results will also vary class by class. Photovoltaic cells can be made as complicated as you wish. Misconceptions can always be addressed during discussion. One of the harder concepts of photovoltaic cells might be the science behind semiconductors. I have found a pretty good simulator from Phet simulations.

Learner Objectives

1. Understand the ideas behind “Energy Crisis”
2. Terminology of photovoltaic cells
3. Understand the workings of a photovoltaic cell
4. Determine the pros and cons of solar cells

National/State/District outcomes related to this lesson

National Science Education Standards CSMEE

Science as Inquiry standards

Abilities necessary to do scientific inquiry

Understanding about scientific inquiry

Science in Personal and Social Perspectives

Natural resources

Environmental quality

Wisconsin State Standards:

D.12.11 Using the science themes\*, explain\* common occurrences in the physical world

H.12.3 Show how policy decisions in science depend on social values, ethics, beliefs, and time-frames as well as considerations of science and technology

G.12.5 Choose a specific problem in our society, identify alternative scientific or technological solutions to that problem and argue it merits

Learner Assessments

1. How will I know that the students have learned?
   1. Since this subject is going to be taught through a cooperative lesson plan, assessment will occur through discussion and group interaction. In addition to this subjective form of assessment, the student will also have qualitative assessment when they measure the final output of the solar energy they measured.

Instructional Procedure

1. Attention Getting Opener
   1. Power Generation by Fuel slide. (It would nice to show the John Stewart clip but it is long and has some NSFW content)
   2. What questions does this slide create in your minds?
   3. What part seems to be the most alarming?
   4. What is a developing country?

1. Statement of Purpose – The purpose of this lesson is to inform my class about the energy crisis that will be faced by our country and our world. I would like to try and get them thinking about renewable energies, more specifically about solar energy.
   1. Over the next couple days we are going to be talking about solar energy and how it plays a role in developing our countries renewable energy sector. We will look at both advantages and disadvantages of using this technology. At the end I will give a small presentation of the research I participated in while working at NREL.
2. Connection to Previous Learning – How will I build on students’ prior knowledge?
   1. Prior knowledge of what a simple circuit is will help the students as they work out the lab following the short direct instruction on photovoltaic cells. I believe the lab will be a good example of series versus parallel circuits because students will directly see the change on the ammeter.
   2. Fossil fuels are an important term in today’s society. By studying renewable energies and our nation’s energy crisis, students will have a better understanding of where their energy is coming from.
3. Teacher Modeling/Demonstration
   1. I like the idea of cooperative learning but I sometimes feel it is hard to implement with new material. That is why I am including a free time for the students to experience the photovoltaic cells prior to the small direct instruction portion.
   2. I will include a rechargeable battery, LED, and small light bulb for the students to play with. This will hopefully show them some pros and cons of PV cells. This will be important because I want to the students to have an authentic learning experience prior to my instruction. I got this idea from working in the lab here at NREL. There were so many concepts that I covered before in my classes at Marquette that became less abstract as I was able to work with them in the lab.
4. Check for Understanding
   1. The check for understanding will come from multiple places in this lab. The journal in the beginning of the class will help set up concepts and give me an idea of what ideas my students have on renewable energy.
   2. How they interact during the free time will also give me a chance to see what they know about simple circuits. The final check will understanding will come from the closing lab they complete. Because I am adding a section on renewable energy, it will be my intention for the students to have some thought provoking answers in my questionnaire. I want the students to have an idea of the impact our carbon-based economy has on our planet.

1. Student Activity
   1. Refer to attached file: Experiment\_with\_PV\_Cells.pdf pages 9-11. Since I am modifying the lab from that lesson I will have my own question sheet. The lab will completed in groups but the write up will be individual.
   2. The write up will defer from the one included in the pdf file

1. Conclusion
   1. At this point I will include the high school level elevator talk about my research here at NREL

My research at NREL was focused on graphene. Graphene is a carbon material that forms as a single layer. Think of it as a piece of paper only one atom thick. It has a potential to be a great conductor that is also transparent which makes it a good fit for photovoltaic cells. For graphene’s full potential to be realized, multiply layers would need to be applied to a support substrate. We grow the graphene on copper slides in a furnace. This is done by flowing a gas that contains carbon, such as methane, over the slides. The copper slides soak up the carbon until they cannot hold it anymore. At this point, carbon begins to collect on the surface. Due to the environment of the furnace, the collected carbon on the surface of the copper is the graphene. We then transfer it to silicon slides where we can analyze it. Unfortunately, during the transfer process containments get on the graphene and limit its ability to be a good conductor. As well as inhibit the application of additional layers. My work was focused on removing those containments without hurting the graphene. To do that, we used a process known as annealing; annealing just means to heat something to remove impurities. I would put the graphene through a heating process to try and burn off the containments which would make it easier to apply additional layers to a sample. We found that higher temperature anneals around 450-500°C work best for multiple layer application. The resistances we achieved where between 175 Ω/Sq. and 250 Ω/Sq.

1. Assessment, Evaluation and Grading
   1. The students will receive credit for the journal activity like it was any other day
   2. The free time with PV”s will not be counted towards a grade, it is mainly for an introduction to the material
   3. The final lab grade will be based on attempt and correctly identifying the trends in data
2. Materials
   1. small PV cells
   2. Several sheets of colored transparency film in different colors
   3. Two electrical leads with alligator clips
   4. DC ammeter
   5. DC volt meter
   6. Sour of bright light or access to direct sunlight
   7. Aluminum foil
   8. Protractor