Ceramic Materials in Renewable Energy:
A Module Developed for Hands-On Learning

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Description:
This document is a lesson plan for a short module describing the use of ceramic materials in renewable energy applications for STEM outreach. Colorado State science standards addressed by the module are included. The module is readily adapted for students in grades 1-12. The module was originally drafted for presentation to children aged 7-13 at the Rocky Mountain Camp for Dyslexic Children, thus activities are largely hands-on, driven by physical concepts, and do not rely heavily on reading or writing skills.

Science Standards Addressed (From the Colorado Department of Education)
http://www.cde.state.co.us/scripts/allstandards/COStandards.asp?stid=7&stid2=0&glid2=0

Standard 1 - Physical Science

- High School: Outcome 5: Energy exists in many forms such as mechanical, chemical, electrical, radiant, thermal, and nuclear, that can be quantified and experimentally determined.
- High School: Outcome 6: When energy changes form, it is neither created nor destroyed; however, because some is necessarily lost as heat, the amount of energy available to do work decreases.
- 8th Grade: Outcome 2: There are different forms of energy, and those forms of energy can be changed from one form to another – but total energy is conserved.
- 6th Grade: Outcome 1: All matter is made of atoms, which are far too small to see directly through a light microscope. Elements have unique atoms and thus, unique properties. Atoms themselves are made of even smaller particles.
- 6th Grade: Outcome 2: Atoms stick together in well-defined molecules or are packed together in large arrangements. Different arrangements of atoms into groups compose all substances.
- 6th Grade: Outcome 3: The physical characteristics and changes of solid, liquid, and gas states can be explained using the particulate model.
- 4th Grade: Outcome 1: Energy comes in many forms such as light, heat, sound, magnetic, chemical, and electrical.

- 3rd Grade: Outcome 1: Matter exists in different states such as solids, liquids, and gases and can change from one state to another by heating and cooling.
- 2nd Grade: Outcome 1: Changes in speed or direction of motion are caused by forces such as pushes and pulls.
- 1st Grade: Outcome 1: Solids and liquids have unique properties that distinguish them.

Standard 2 – Life Science
8th Grade: Outcome 1: Human activities can deliberately or inadvertently alter ecosystems and their resiliency.

Standard 3 – Earth Systems
- High School: Outcome 5: There are costs, benefits, and consequences of exploration, development, and consumption of renewable and nonrenewable resources.
- 8th Grade: Outcome 1: Weather is a result of complex interactions of Earth's atmosphere, land and water, that are driven by energy from the sun, and can be predicted and described through complex models.
- 6th Grade: Outcome 3: Earth's natural resources provide the foundation for human society's physical needs. Many natural resources are nonrenewable on human timescales, while others can be renewed or recycled.
- 5th Grade: Outcome 1: Earth and sun provide a diversity of renewable and nonrenewable resources.
- 3rd Grade: Outcome 1: Earth's Materials can be broken down and/or combined into different materials such as rocks, minerals, rock cycle, formation of soil, and sand – some of which are usable resources for human activity.
- 2nd Grade: Outcome 1: Weather and the changing seasons impact the environment and organisms such as humans, plants, and other animals.

Objective: Introduce the fundamental concepts of ceramic materials to the students and the applications of ceramics in renewable energy applications. Explain the concept of energy and the various renewable sources of energy. Demonstrate the role of ceramic materials in harvesting each of these energy sources. Illustrate career options in these areas.

Materials:

- For Energy Introduction
  - Rubber Band
- For Ceramics Introduction:
  - Ceramic Vegetable peeler (any other easily obtainable materials from the ceramic product list)
- For Student Activity:
  - Solar powered cars (1 or 2 students per car)
    - Use sunwindsolar.com or similar product
  - Optional: Compact solar panels with LEDs and wiring with alligator clips
    - Use when no direct sunlight available
    - High intensity light could be used indoors
- For Ceramic Renewable Energy Demonstration (photos are provided if these materials are not accessible)
  - Ceramic turbine bearings
  - Raw photovoltaic ceramics
  - Fuel cell ceramics
  - Battery ceramics
- Other Demo Supplies (Optional)
  - Model wind turbine
    - Example of wheel bearings (fidget spinner)
- Photo book of ceramic products, renewable energy products, and related careers

Timeline:

1. Energy Introduction (10 minutes)
2. Solar Car Activity (15 minutes)
3. Ceramics Introduction (5 minutes)
4. Renewable Energy Ceramic Demonstrations (15 minutes)
5. Questions (5 minutes)

<u>Procedure:</u>

1. Energy Introduction

Explain the concept of energy and the various forms of energy. Provide examples of energy applied to human activity.

-Background information

Energy is the concept of one object's ability to do some sort of work on another object. This can be moving an object or turning on devices. Energy can come in multiple forms such as Kinetic Energy, Potential Energy, Chemical Energy, etc.

Energy can be converted to other forms of energy. A simple example would be the pull and release of a rubber band. When pulling on a rubber band, the rubber band is gaining potential energy, and when releasing the rubber band, the potential energy is converted to kinetic energy.

Chemical energy is another important form of energy and can be explained with a simple battery. A battery is essentially a series of chemicals which have a stored amount of chemical energy and when the battery is used, the chemicals interact and convert their chemical energy to electrical energy.

Energy can be found in our everyday lives as we've just given a few examples. Could anyone suggest some examples of energy usage in your own lives? Where can we find energy in your school? Your home? This camp?

We utilize various forms of energy in our everyday lives. A common example is a car engine. We input chemical energy, gas or diesel, in our engine and the engine converts that chemical energy into kinetic energy.

Introduction to Renewable Energy

Discuss the sources of energy in terms of renewable and non-renewable options. Address the pros and cons of each.

-Background information

There are a variety of different ways to get energy that we use throughout the world, but we can categorize these energies based on their sources. There are renewable and nonrenewable energies that we utilize all over the world. A nonrenewable energy, like fossil fuels and nuclear energy, is one that comes from sources which will eventually become depleted, and a renewable energy, like wind, solar, geothermal, and hydroelectric energy, is an energy that comes from an energy source which won't become depleted on human time scales.

The big advantage of nonrenewable energies such as fossil fuels is the low cost and the long history of fossil fuel infrastructure in place all over the world; however, the processing and burning of fossil fuels can produce harmful chemicals which can be released into the atmosphere and aquatic systems. Renewable energies can more easily produce energy without the release of pollutants, but they sometimes have higher upfront cost or additional complexities relative to fossil-fuel-based energies.

There are a variety of ways that we can harness renewable energy. A common example that you may have already seen would be wind energy. You may have seen huge wind turbines or smaller wind mills. Wind mills and wind turbines essentially do the same thing; they convert the renewable wind energy to a different type of energy. The wind blows and spins the blades creating kinetic energy. This kinetic energy is then converted to a more useful type of energy, like electricity.

2. Solar Car Activity

This activity requires direct sunlight on a relatively flat surface. Task the groups of 1 to 2 students to investigate the operation of a preassembled solar car. At the end of the activity have the groups share their observations and hypotheses with the class. Discuss the basic utility of photovoltaics and the forms of energy involved.

3. Ceramics in Renewable Energy

Introduction to Ceramic Materials

Begin with a discussion about the long history of ceramics and the wide range of applications. Give examples through picture and/or actual ceramic objects (pictures provided at the end).

-Background information

Ceramic materials have been around for a long time. The production of clay ceramics dates back to 24,000 BC, but in the years around 14,000 BC, the first ceramic tile was created beginning the production of application based ceramics [1]. Today ceramics cover a wide breadth of properties and applications spanning from vegetable peelers and knifes to graphite tennis racquets and space shuttle tiles. Ceramics are a type of solid and are used because of their unique properties compared to other materials. They are typically hard and tolerate high heat but are relatively brittle and vulnerable to fracture.

4. Renewable Energy Ceramic Demonstrations

Present each different type of renewable energy individually; solar, wind, batteries, and fuel cells. Use the photos to illustrate the technology and how it works. Point out the components that are ceramic materials and why ceramics are ideal for the applications. Provide hands-on materials for examples if possible. Encourage them to ask and answer questions throughout. Push their imaginations on the possibilities of these technologies.

Discuss the different types of careers that are available in renewable energy. The research and design is conducted by scientists and engineers. The assembly of the materials to create a product is done my manufacturers. And the renewable energy products are implemented by builders and installers.

5. Questions

Review the fundamental questions that the students should be able to answer. What is energy? What is renewable energy? Why is renewable energy important? What types of materials are used for this technology? Where else could humans use renewable energy?

Talking Points

1. **Introduction**
    a. Energy
        - What is Energy?
        - Where can we find energy?
        - What kind of work can be done to something?
        - Kinetic Energy, Potential Energy, Chemical Energy, etc.
        - Rubber band example explaining Potential vs. Kinetic Energy
        - Chemical Energy explained with batteries
        - Where can we find energy in our everyday lives?
        - Common examples of energy utilization? Car engine.
        - Could anyone suggest some examples of energy usage in your own lives? Where can we find energy in your school? Your home? This camp?

    b. Renewable Energy
        - What is renewable energy?
        - What's the difference between renewable and nonrenewable energies?
        - What are sources of renewable and nonrenewable energies?
        - What are the pros and cons of both types of energy?
2. **Solar Car Activity**
    a. Where is the energy coming from?
    b. What kind of energy is involved?
    c. How can we make the cars go faster?
    d. How many panels would a regular car need?
    e. What else can we power with solar energy?
3. **Ceramics in Renewable Energy**
    a. Ceramics
        - There are 3 main solid material types that we usually encounter in our everyday lives: Ceramics, Metals and Plastics. Ceramics are probably one of the most common materials that you see in your everyday lives.
        - Ceramics is an ancient field, as some of the first ceramic pieces were made back in 24,000 B.C.E and resembled animals and humans (Image provided)
        - Today, ceramics cover a wide range of materials going from coffee mugs to space shuttle tiles and other high tech applications. (Images provided)
        - These materials are made by combining a metal with another element which is usually oxygen, carbon, nitrogen or boron in order to make a powder.
        - Some of the big advantages of ceramics are that they usually have high melting temperatures and that they are usually very hard.
        - The biggest drawback to ceramics is that they are often brittle, meaning that they easily break if dropped.

    b. Where can we find Ceramics in Renewable Energy?
        - Recall types of renewable energy

- Identify ceramic components
- Unique properties that make them perfect for renewable energy:
    1. ability to store chemical energy (battery)
    2. wear resistant (wind turbine)
    3. ability to convert light into energy (solar)
    4. ability to convert between chemical and electrical energy (fuel cell)

4. **Renewable Energy Ceramics Demo**
    a. Solar Cells
        - How many cells to power different technology?
        - Improving efficiency
    b. Wind Turbine Bearings
        - Wheel bearing explanation
        - Other types of turbines
    c. Batteries
        - Storing energy from other sources
    d. Fuel Cells
        - Batteries that use fuel (water byproduct)

5. **Questions, Careers**
    a. Scientist/Engineer
        - Design and research renewable energy technology
    b. Manufacturing
        - Assemble the technologies for others to use
    c. Builder/Installer
        - Apply the renewable energy technology to the world

<u>Discussion Questions/Takeaway Information:</u>

1. What are ceramics?
2. What is energy?
3. What is renewable energy?
4. What are some ceramics used in renewable energy?

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References:

[1] D. De Guire, 'History of Ceramics | The American Ceramic Society', Ceramics.org, 2015. [Online]. Available: http://ceramics.org/learn-about-ceramics/history-of-ceramics. [Accessed: 08- Jun- 2015].

Ceramic Products

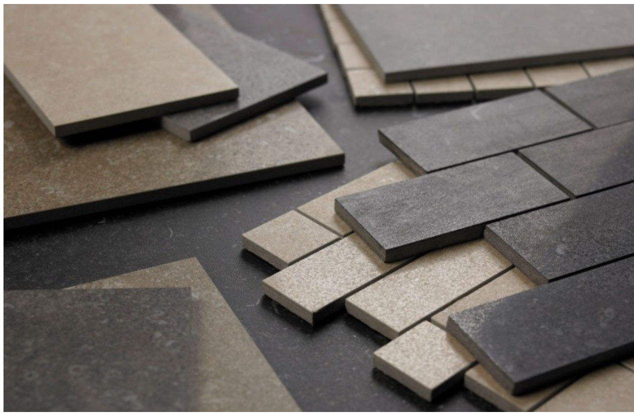
- Ceramic vegetable peeler, kitchen knives

- Automotive Parts/Aerospace Parts
    - Engine components including brakes, gears, and bearings
        - Ceramic Brake Pads

    - Aerospace tiles

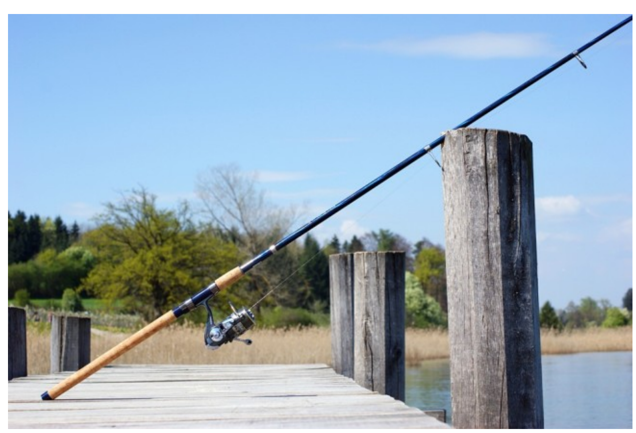
Ceramic Products

- Floor/Roof Tiles




- Toilets/Sinks/Tubs

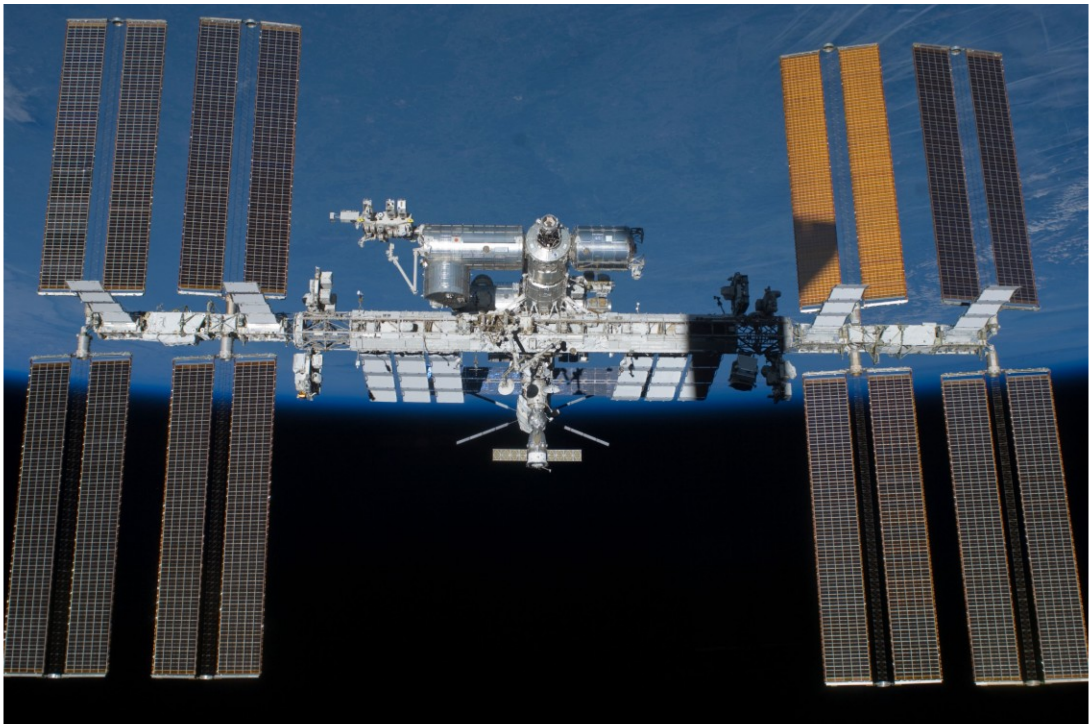

- Some sports equipment
    - Graphite tennis rackets, golf clubs, fishing poles

Ceramic Products

- Plates/Coffee Mugs/Pottery

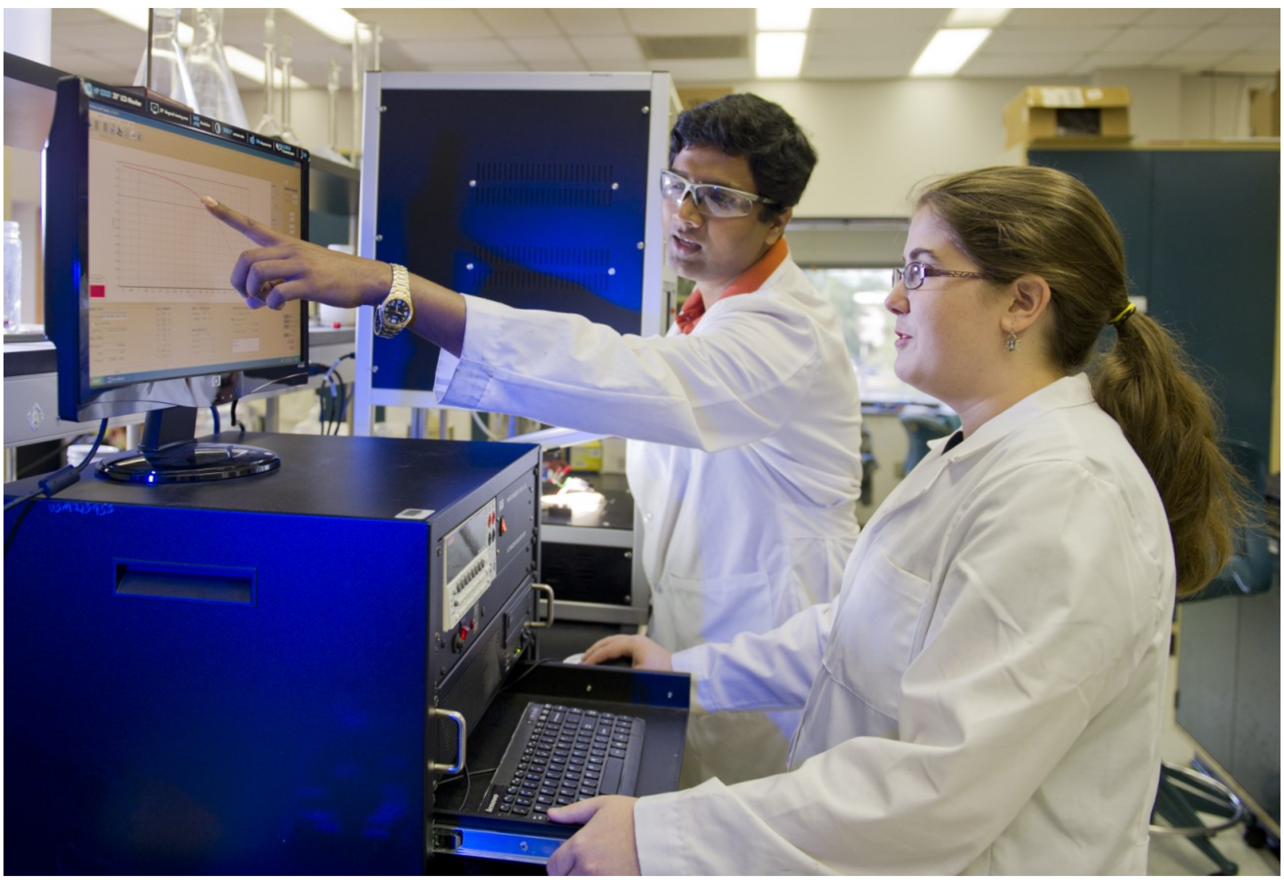
<u>Renewable Energy – Solar</u>



www.nasa.gov

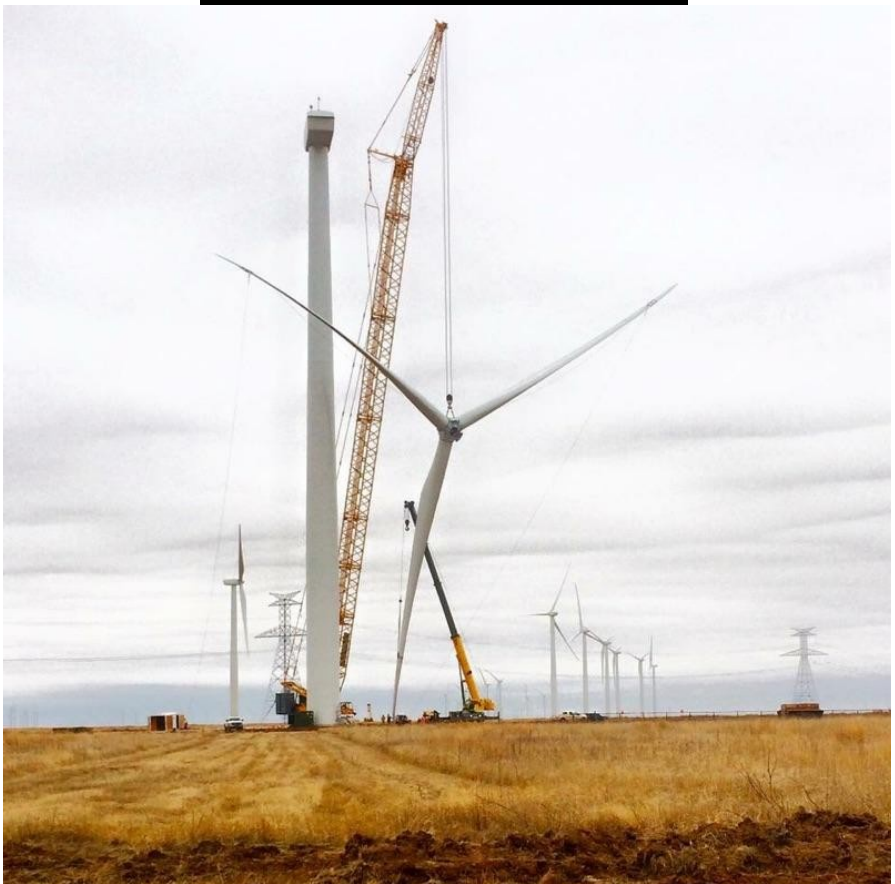
http://davebuemi.com/wp-content/uploads/2010/09/china-solar-factory.jpg

http://www.greenstatepower.com



http://news.usm.edu/sites/default/files/Solar%20cells.jpg

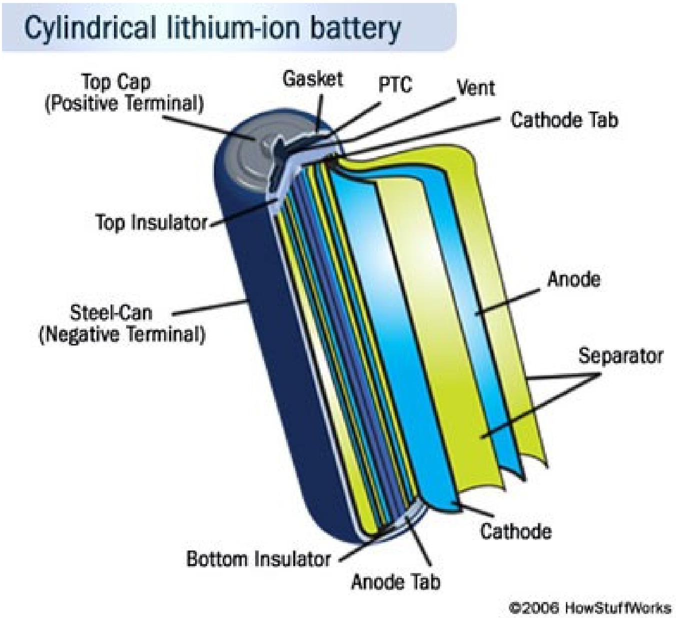
Renewable Energy – Wind



Courtesy of Travis Johnson, LM Wind Power

Renewable Energy – Batteries and Fuel Cells

- Batteries



- Fuel Cells

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