UTAH OFFICE OF
ENERGY DEVELOPMENT

Exploring Energy Conversions with Alternative Vehicles

Grade/Subject: Earth & Space Science

Strand & Standard ESS.4.3 Evaluate design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios on large and small scales. *Define the problem, identify criteria and constraints, analyze available data on proposed solutions, and determine an optimal solution.* Emphasize the conservation, recycling, and reuse of resources where possible and minimizing impact where it is not possible. Examples of large-scale solutions could include developing best practices for agricultural soil use or mining and production of conventional, unconventional, or renewable energy resources. Examples of small-scale solutions could include mulching lawn clippings or adding biomass to gardens. (ESS3.A, ETS1.A, ETS1.B, ETS1.C)

Lesson Performance Expectations: Students will perform a cost and environmental analysis of traditional and new alternative energy cars. Describe different alternative fuels and the vehicles they power.

Materials:
Solar cars for the phenomenon, computers.

Time: Three 45 minutes periods or more.

Teacher Background Information:

VOCABULARY

- **Alternative Fuels** – Vehicle energy sources made primarily from resources other than petroleum. Some alternative fuels are petroleum products, but all are alternatives to traditional petrol and diesel fuels.
- **Energy** – The ability to do work or cause change.
- **Chemical Energy** – Energy stored in the bonds of chemical compounds (atoms and molecules)
- **Mechanical Energy** – Energy associated with the motion and position of an object
- **Thermal Energy** – Internal energy of an object due to the kinetic of its atoms and/or molecules
- **Kinetic Energy** – Energy in the form of motion.
- **Potential Energy** – Energy that is stored based on the position and composition of an object, which could be changed to release the energy.
- **The Law of Conservation of Energy** – Energy cannot be created or destroyed but only changed from one form to another.
- **Electric Vehicle** – An alternative fuel vehicle, powered in part or entirely by electricity. Types include plug-in hybrid electric vehicles (PHEV), hybrid electric vehicles (HEV), and all-electric vehicles (EV).
- **Natural Gas Vehicle** – An alternative fuel vehicle powered by compressed natural gas (CNG) or liquefied natural gas (LNG). Compressed Natural Gas (CNG) is compressed to a pressure at or above 200-248 bar and stored in high-pressure containers. Liquefied Natural Gas (LNG) – Natural gas (primarily methane) liquefied by reducing its temperature to -260 F.
- **Propane Vehicle** – An alternative fuel vehicle powered by propane, otherwise known as propane liquefied petroleum gas.
- **Biofuel Vehicle** - A renewable, alternative fuel made from recycled oils, oils, sugars, or starches.
- **Photosynthesis –** The manufacture by plants of carbohydrates and oxygen from carbon dioxide and water in the presence of chlorophyll, with sunlight as the energy source.

- **Basic combustion** reactant area energy source (Gas) mixed with oxygen and an ignition source. The products are Carbon Dioxide and water.

BACKGROUND INFORMATION

Utah Greenpower Electric Car Challenge video. (1.36 min)

- What are alternative fuels, and why are they important? Alternative fuels are energy sources made primarily from resources other than petroleum. Some alternative fuels are petroleum products, but all are alternatives to traditional petrol and diesel fuels. Expanding the use of alternative fuels can help individuals save money and contribute to improved air quality. The development and utilization of these fuels diversify the transportation system, lower vehicle tailpipe emissions, and enhance energy security. The most prevalent alternative fuels are electricity, natural gas, propane, and hydrogen, in that order.
- *Electric Vehicle* is a plug-in hybrid electric vehicle (PHEV) that operates on a battery pack that can recharge from an external source of electricity and gasoline. An example is a Toyota Prius.
- A hybrid electric vehicle (HEV) runs on a combination of gasoline and electricity generated during braking. An example is a Chevrolet Volt.
- An all-electric vehicle (EV) operates only on electricity stored within a battery that needs to recharge. Examples are a Nissan Leaf, and Tesla Model S
- *Natural Gas* Vehicles store compressed natural gas (CNG) in specially designed cylinders. Due to reduced tank capacity, the range of a CNG vehicle is about half that of gasoline-fueled vehicles, but fuel costs are often lower. An example is a UTA CNG bus.
- *Liquefied natural gas* (LNG) is purified and supercooled to a liquid state (at - 260°F)! At this temperature, natural gas occupies only 1/600th of the volume that it does at room temperature. LNG requires large insulated storage tanks, making it well-suited for large vehicles that need to travel long distances. Farm machinery or fleet vehicles may run on LNG.
- *Propane* (Liquefied Petroleum Gas) Vehicle Propane has long been used as a transportation fuel and is the third most common engine fuel globally. It has an operational range, power, acceleration, and cruise speed almost equivalent to gasoline-powered vehicles.
- *Biofuel Powered Vehicles* Biodiesel is a renewable, alternative fuel made from recycled oils, sugars, or starches. Biofuels gain their energy from photosynthesis using the light energy of the sun. Ethanol is grain alcohol produced mainly from corn and sometimes from sugar cane or rice straw. Methanol, another alcohol alternative fuel, can be produced from plant material, but natural gas is the main source of its production.
- *Hydrogen Vehicle* Hydrogen is a flammable gas that has been called the fuel of the future. It is the most abundant element in the universe but generally does not occur naturally as a gas on Earth. Instead, hydrogen atoms are generally part of larger molecules, such as water. Producing hydrogen gas from water takes energy. Through a process called electrolysis of water (the decomposition of water), an electric current is passed through a water molecule and separates the Hydrogen (H) and Oxygen (O) chemical bond. Examples of hydrogen vehicles are the Toyota Mirai, the Hyundai Nexo, and the Honda Clarity.

Student Background Knowledge:

Students need a basic knowledge of transportation and research skills.

Teacher Step by Step: A 3-d lesson should insist students do the thinking. Provide time and space for the students to experience the phenomenon and ask questions. The student sheet provided below provides guidance but is only an example of how students might respond.

1. **Introduce *Phenomenon:*** *run a solar-powered car on the table (with lights) or outdoors in the sun.*
2. Ask what makes this solar car run.
3. Ask what makes your family car run.
4. Ask what are the by-products of a car running. (the teacher may talk about by-products of combustion, which are carbon dioxide and water, and their effect on the environment.)

5. Students should do the worksheet/quiz at the end of the lesson plan to help them understand where and which alternative fuels are available in Utah.

6. **Day 1** The student should research and then do a cost analysis of family cars (minimum of 3) that use different types of fuel, including gas, diesel, electric, hybrid, natural gas, propane and Hydrogen. Things to include in the analysis are the initial retail cost of the car, cost of potential repairs, operation cost per 500-mile trip, fuel availability, and the car's performance.

7. **Day 2** Students should then research the potential environmental impacts of each car and how that affects them as individuals.
8. Students should write their summary paper telling which car they would buy and why they chose the car they did. Students should include costs and environmental impact. The reasoning should include why they think this evidence is important.

Assessment of Student Learning. The student's claim identifies a type of car. The evidence is located in the student research, and the reasoning is a rational discussion of how the students' thinking resulted in their claim.

Standardized Test Preparation:

Exploring Energy Conversions with Alternative Vehicles

1. Which factors currently limit the ability of all-electric cars to travel long distances? Choose all that apply.
    a. The mileage range of the vehicle.*
    b. The reduced mileage they get.
    c. The slower speeds they can travel.
    d. The spacing of charging facilities.*

2. How is the transportation and storage of natural gas different from the gasoline used in most cars today?
    a. Natural gas must remain under pressure.*
    b. Natural gas can be moved through pipelines.
    c. Natural gas cannot be stored in tanks.
    d. Natural gas cannot be placed in the same gas tank.*

3. What challenges do solar car manufacturers have to create a car that can travel long distances? Choose all that apply.
    a. Developing a long-lasting battery.*
    b. Creating a lightweight but strong car body.*
    c. Developing solar panels that capture maximum solar energy. *
    d. Finding new ways to charge solar panels without sunlight.

4. What advantage do electric motors have over fuel-based engines? Choose all that apply.
    a. They have fewer moving parts.*
    b. They emit little exhaust.*
    c. They are quiet.*
    d. They have more power.

Extension of lesson: Have students design a car or transportation system that is environmentally friendly and cost-effective for a city**.** Students could also make an advertisement for their favorite car from the list.

Career Connections: City Planner, Mechanical Engineer, Environmental Scientist

Exploring Energy Conversions with Alternative Vehicles

Name_____

Phenomenon: Watch the phenomenon of the solar car running. Ask three questions about what you see.

1.

2.

3.

Day 1

Take a tour of Utah's alternative fueling stations at this website.

Then answer the following questions from the website.

Where is the closest fueling station to your home?_____

How many fuel or charging stations are in Utah in the following categories?

Biodiesel _____

Hydrogen _____

Compressed Natural Gas_____

Liquefied Natural Gas Electric ___

Ethanol _____

Here are some more optional websites to discover more about alternative fuels and fuel efficiency in Utah and beyond.

Utah Office of Energy Development

Utah Transit Authority, Trip Planner

Utah Department of Transportation, TRAVELWiseTM

U.S. Department of Energy, Alternative Fuels Data Center

U.S. Department of Energy, Fuel and Emissions Calculators

Cost analysis

Pick three types of cars to research from this list: Gas, diesel, electric, hybrid, natural gas, propane, and Hydrogen

Criteria

The energy source for car	Cost of car	Repair Costs	Cost of fuel	Seating space, durability, acceleration	Fuel availability

Day 2 Research the potential environmental effects of each of the cars you picked. Remember to look at the raw materials it would take to produce that car.

Criteria	Environmental impact

Summary:

Make a **claim** concerning the automobile you think is most practical under current conditions.

What **evidence** for this research supports your claim?

What **reasoning** did you use?