Driving Green

Student Objective
The student:
- will explain how combustion vehicles contribute to our pollution and climate change problems
- will explain the benefits to health and air quality of driving an electric vehicle
- will calculate the reduction in CO_2 emissions from the operation of electric vehicles
- will explain how photovoltaics can be used to decrease transportation emissions.

Key Words:
combustion
carbon dioxide (CO_2)
emission factor
external costs
fuel efficiency
full cost assessment
net energy value
NOx
particulate matter
systems perspective
volatile organic compounds (VOC)

Materials:
- Laboratory Manual
- video recording equipment (phone, tablet, camera, etc)

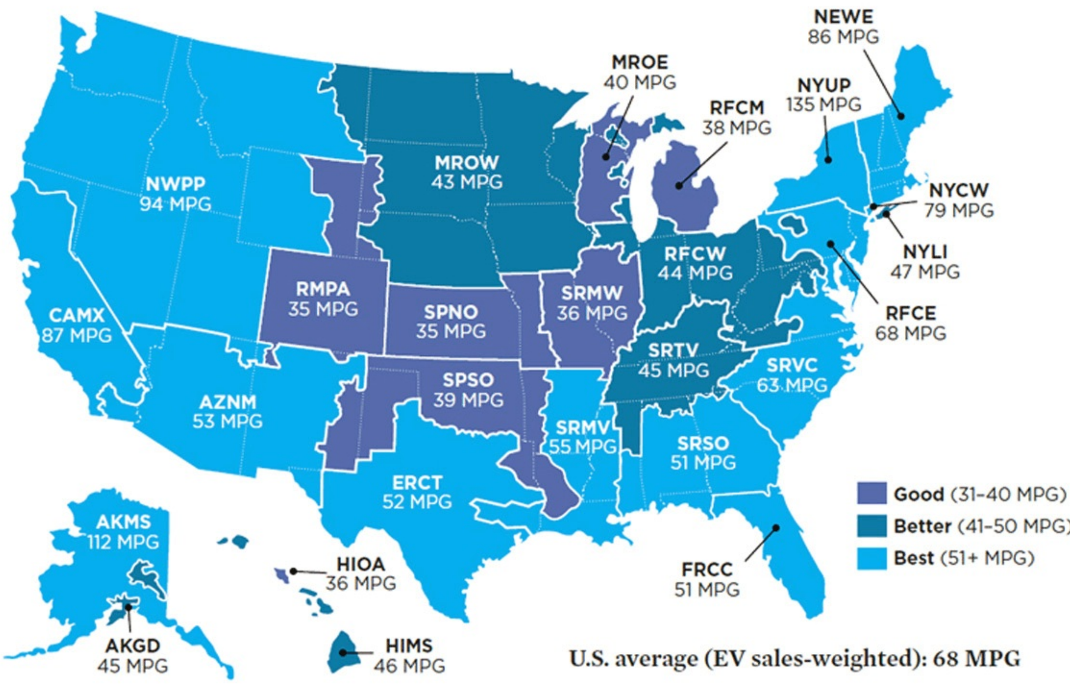
Time:
1 class for discussion and video assignment
2 - 3 classes for video work (unless assigned as homework
1 class for video presentations

Background Information

It is obvious that gasoline combustion vehicles have more tailpipe emissions than electric vehicles (which have none). However, to compare electric vehicles to internal combustion engine cars, you must compare not just the cars themselves, but the complete life cycle–manufacturing, driving & maintenance, and end of use recycling.

In comparing the manufacture of electric vehicles and combustion vehicles, battery electric vehicle production results in higher emissions, mainly due to the materials and manufacture of the lithium-ion battery. The Union of Concerned Scientists in their study determined that under the average U.S. electricity grid mix, the mid-size, midrange electric vehicle battery adds a little over 1 ton of emissions during its manufacture, which is a 15% increase over the manufacture of a mid-size internal combustion vehicle. However, the extra emissions are rapidly negated by reduced emissions while driving, so that the “pay back” (offset) occurs at 4900 miles–about 6 months of driving.

To compare fueling and driving emissions, the emissions from the power plants that generated the electricity for electric cars must be taken into account, as well as the emissions from mining operations to extract that fuel. And for gasoline cars, emissions from the gasoline stations themselves, the refineries, oil tankers and mining must be accounted for. Because many of these "upstream" costs are region specific and others are difficult to determine (i.e. health costs), it can be very difficult to make a true comparison on the full life cycle. In 2012 and 2014, the Union of Concerned Scientist released life cycle analyses of emissions from electric and gasoline powered vehicles that tracked the global warming emissions that come from the production of gas and electricity as well as from driving. They put together a map for the United States that shows by regional electricity grid, the fuel economy rating that a gasoline vehicle would need in order to achieve the same greenhouse gas emissions as the average electric vehicle (below).



Their full report can be read from the link here:
http://www.ucsusa.org/clean-vehicles/electric-vehicles/life-cycle-ev-emissions

The tailpipe greenhouse gas (CO_2) emissions from a mid-sized passenger car using gasoline is 8,887g CO_2 per gallon of gas, or 411 g of CO_2 per mile for the same mid-sized car.

Procedure (assignment day)

1. **Engage:** Show the video *Electric Cars and Global Warming Emissions* by the Union of Concerned Scientists (link is listed In Internet Sites section).
2. Lead a class discussion about the video. Points to discuss should include:
   - Although more materials and energy are needed to produce a battery car (mainly from the battery) those emissions are offset in less than a year of driving.
   - To accurately compare combustion and electric vehicles their "life cycle" emissions and costs must be taken into account.

- To compare fueling and driving emissions, the emissions and energy used to get either the gasoline or electricity to the vehicle must be taken into account. (It would be useful to have the students list the steps in both processes.)

3. Ask students how electric vehicles fit into a study of solar. Lead a short discussion. Students should be able see the connection--producing the electricity for electric vehicles from photovoltaics. Many methods exist in the present as well as in ideas for the future (solar roadways for example). Let the students brainstorm ideas for integrating photovoltaics into the transportation system.
4. Show the class two or three student produced videos on cars and air pollution (there are some listed in the Internet Sites section). Tell them these are student produced videos
5. Get the students talking about the videos...both pros and cons of each. Did some "turn them off" from over-negativity? Were some too long? Were the facts accurate? Were there too many facts....or not enough? (etc.)
6. **Explore:** Divide the students into project teams. Explain that they will be producing a video on one aspect of transportation air pollution, the benefits of electric vehicles, or the drawbacks of using fossil fuels for transportation.
7. The guidelines for the videos are:
    - Videos are to be at least 2 minutes long, but no longer than 4 minutes.
    - All team members must participate in the video in some way.
    - The videos may be produced in any way the team decides–live action, still photos with narration, animation, etc.
    - The videos will be presented to the class who will evaluate them according to the Video Evaluation Form; however the two main considerations when making the videos are creativity and factual accuracy.
8. Assign a due date and assist the teams as needed. *(Note: The transportation pollution video may be used as a classroom project, or assigned as a homework project with smaller groups. It is designed to evaluate student knowledge and provide an avenue for students to use their creative or technical skills.)*

Procedure (presentation day)

1. Hand out copies of the rating sheet and have each student "x" out their team's row on the table (they can not assess their own video).
2. **Explain / Elaborate:** Have all the students take notes during the group videos including what they like and dislike about each presentation.
3. **Evaluate:** After all the video presentations are completed, have students discuss and rate the other group videos on a scale of 1 - 10 (with 10 being the highest) for each of the criteria and complete their self evaluation section.
4. Collect the group ratings; tally the scores and announce the group with the highest score in each category. Lead a classroom discussion of what was done to make an effective video giving credit to as many groups as possible. Agree or disagree with the class ideas as needed. Possible discussion points:
    - What group (or groups) covered their topic the best?
    - What group (or groups) had the most creative and original ideas? Why?
    - What group (or groups) demonstrated the best video skills? Why?
    - What group (or groups) demonstrated working effectively?

- Do the class' tallied scores agree with the discussion?

Answer Key

1. Answers will vary depending on the geographic location of your school, but students should calculate the number of electric cars on the road, then multiply that number by the difference in emissions (in their zip code area) between gasoline and battery electric vehicles.
2. The final answer will vary depending on your geographic location, but the students should calculate that 22,568,965 cars will be purchased each year, and that 25% of that total is 5,642,241. They should then multiply that number by the CO2 reduction factor for your area and convert the answer to tons for the per year figure. Simple multiplication will then give them all five years.

2b. Same procedure, but with 60% of the cars

3. Answers will vary, but students should understand that difficulties can arise when changing people's attitudes and behaviors.
4. Answers will vary depending on the emission value of the electricity in your area. However, students should realize that on average there will be a 2/7 reduction in grams of CO_2 per mile when you can charge your car 2 days out of the week with emission free electricity.
5. Answers will vary depending on the emission value of the electricity in your area, but the reduction should be 5/7 of the original battery electric vehicle CO_2 value.
6. Zero

Key Words & Definitions

- **combustion** – burning; a chemical reaction that involves the rapid combination of a fuel with oxygen
- **carbon dioxide (CO_2) –** a colorless, odorless gas found in our atmosphere. It is a waste product in our bodies, and is also produced by burning fossil fuels.
- **emission factor** – amount of pollutant emitted per unit of fuel consumed
- **external costs** – a cost or benefit other than those involved in the activity that produced it. For example, the pollution caused by using gasoline for transportation which isn't included in the price of gas, and asthma caused by power plant emissions which isn't included in the price of electricity.
- **fuel efficiency –** the capacity of an engine to obtain energy from fuel; miles traveled per unit of fuel
- **full cost assessment –** defining costs so as to include all those associated with the manufacture, use and disposal of a product
- **net energy value (NEV) –** an efficiency metric that describes the lifecycle energy consumption relative to the energy value of the fuel
- **Nox** – oxides of nitrogen, especially as atmospheric pollutants
- **particulate matter –** the sum of all solid and liquid particles suspended in air. This mixture includes both organic and inorganic particles, such as dust, pollen, soot, smoke, and liquid droplets.

- **systems perspective** – taking into account all of the behaviors of a system as a whole in the context of its environment
- **volatile organic compounds (VOC)** – any compound of carbon (excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, and ammonium carbonate), which participates in atmospheric photochemical reactions. Indoor VOC are typically caused by cleaning and other products used, and outdoor VOC are typically produced during manufacturing. The EPA regulates outdoor VOCs mainly because of their ability to create photochemical smog under certain conditions.

Related Research

1. Interview parents, grandparents and other adults about how their attitudes toward fossil fuel use and alternative energy sources have changed in their lifetime. Have their attitude towards fuel efficiency changed? Electric cars? If so, have they noticed these new attitudes reflected in car design? Have these changes affected their behavior as consumers?
2. Research solar car competitions including the American Solar Challenge, the Dell-Winston Solar Car Challenge, and the World Solar Challenge. How many kW of photovoltaics do these race cars have integrated into their body design? How many pounds of batteries do they carry onboard? How far do they typically race in one day? What is their top speed and their cruising speed? Create an informative article, poster or presentation to share with other students in your class or school.
3. Read the article, *Solar May Never Power Your EV, But You Can Still Drive on Sunshine*, **https://www.wired.com/story/solar-power-electric-cars**/, (Wired, July 2018). Research multijunction (gallium) photovoltaic panels and perovskite solar cells. Write and illustrate an informative article on the future of vehicles with photovoltaics integrated into their design, and how they would work.

Related Reading

- ***Car Wars: The Rise, the Fall, and the Resurgence of the Electric Car*** by John J. Fialka (Thomas Dunne Books, 2015)
  Award-winning former Wall Street Journal energy and environmental reporter, John Fialka documents the history of the electric car and battery technology from the M.I.T./Caltech race between prototypes in 1968, through the U.S. initial rejection of electric cars until today's growing obsession with the technology.

Internet Sites (student videos):

https://www.youtube.com/watch?v=_Rd8znLxpSM
Transportation 101, Transportation and its effect on climate change.

https://www.youtube.com/watch?v=FLFA38trGO0
Car Pollution (animation).

https://www.youtube.com/watch?v=Q8gl3tetgFg
Air Pollution Letter to the Prez (speed drawing).

https://www.youtube.com/watch?v=F4fLu4Sqv8c

The Effect of Transportation on Climate Change (stresses solutions).

Internet Sites

http://www.ucsusa.org/EVlifecycle

Electric Cars and Global Warming Emissions, Union of Concerned Scientists video compares the emissions from manufacturing, disposal and daily driving of a combustion vehicle and a plug-in electric vehicle. The site also includes EV and gasoline life cycle analysis and a map of the U.S. showing pollution rating equivalencies for fossil fuel vehicle mpg and electric power plant emissions.

https://www.epa.gov/energy/power-profiler

Environmental Protection Agency, Power Profiler page lets you input your zip code and see how the fuel mix and air emissions rates in your region compare to the national average.

https://www.wired.com/story/solar-power-electric-cars/

Wired article, *Solar May Never Power Your EV, But You Can Still Drive on Sunshine*, (July 2018), discusses current research in photovoltaics and how PV might be integrated into transportation in the future.

https://www.youtube.com/watch?v=fiTsOaDaXJo

The Economist video, *Why Electric Cars Aren't Always Greener*, presents the argument that how and when the power is produced affects whether the electric car is actually greener than a diesel car.

http://www.ucsusa.org/clean-vehicles/electric-vehicles/ev-emissions-tool

Union of Concerned Scientists interactive emissions calculator. Enter your zip code, make and model of car and find out CO_2 emissions (from the power plant) in your area for that vehicle and how that compares to the national average.

http://fueleconomy.gov/feg/evsbs.shtml

U.S. Department of Energy site - Electric vehicles, fuel economy.

Driving Green

Florida NGSS Standards & Related Subject Common Core

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Nature of Science																					
Standard 1	**SC.912.N.1.**							X													
Standard 4	**SC.912.N.4**		X																		
Earth and Space																					
Standard 6	**SC.912.E.6.**						X														
Life Science																					
Standard 14	**SC.912.L.14.**						X														
Standard 17	**SC.912.L.17.**											X		X			X	X	X		X
Mathematics Standards		MAFS.912.N-Q.1.3, MAFS.912.A-REI.1.2, MAFS.912.A-REI.2.3, MAFS.k12.MP.1.1, MAFS.K12.MP.4.1																			
Language Arts Standards		**Grades 9 & 10:** LAFS.910.SL.2.4, LAFS.910.SL.2.5 **Grades 11 & 12:** LAFS.1112.SL.2.4, LAFS.1112.SL.2.5																			
Visual Arts Standards		VA.912.S.1.1, VA.912.H.3.3, VA.912.F.3.1, VA.912.3.12																			

Science–Standard 1: The Practice of Science
- SC.912.N.1.7 - Recognize the role of creativity in constructing scientific questions, methods and explanations.

Science–Standard 4: Science and Society
- SC.912.N.4.2 - Weigh the merits of alternative strategies for solving a specific societal problem by comparing a number of different costs and benefits, such as human, economic, and environmental.

Science–Standard 6: Earth Structures
- SC.912.E.6.6 - Analyze past, present, and potential future consequences to the environment resulting from various energy production technologies.

Science–Standard 14: Organization and Development of Living Organisms
- SC.912.L.14.6 - Explain the significance of genetic factors, environmental factors, and pathogenic agents to health from the perspectives of both individual and public health.

Science–Standard 17: Interdependence
- SC.912.L.17.11 - Evaluate the costs and benefits of renewable and nonrenewable resources, such as water, energy, fossil fuels, wildlife, and forests.

- SC.912.17.13 - Discuss the need for adequate monitoring of environmental parameters when making policy decisions.
- SC.912.17.16 - Discuss the large-scale environmental impacts resulting from human activity, including waste spills, oil spills, runoff, greenhouse gases, ozone depletion, and surface and groundwater pollution.
- SC.912.17.17 - Assess the effectiveness of innovative methods of protecting the environment.
- SC.912.17.18 - Describe how human population size and resource use relate to environmental quality.
- SC.912.17.20 - Predict the impact of individuals on environmental systems and examine how human lifestyles affect sustainability.

Mathematics–Number & Quantity

- MAFS.912.N-Q.1.3 - Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

Mathematics–Algebra: Reasoning With Equations and Inequalities

- MAFS.912.A-REI.1.2 - Solve simple rational and radical equations in one variable, and give examples showing how extraneous solutions may arise.
- MAFS.912.A-REI.2.3 - Solve linear equations and inequalities in one variable, including equations with coefficients represented by letters.

Mathematics–Mathematics Practice

- MAFS.K12.MP.1.1 - Make sense of problems and persevere in solving them.
- MAFS.k12.MP.4.1 - Model with mathematics.

Language Arts–Standards for Speaking and Listening

- LAFS.910.SL.2.4 & LAFS.1112.SL.2.4 - Present information, findings, and supporting evidence clearly, concisely, and logically such that listeners can follow the line of reasoning and the organization, development, substance, and style are appropriate to purpose, audience, and task.
- LAFS.910.SL.2.5 & LAFS.1112.SL.2.5 - Make strategic use of digital media in presentations to enhance understanding of findings, reasoning, and evidence and to add interest.

Visual Arts–Skills, Techniques, and Processes

- VA.912.S.1.1 - Use innovative means and perceptual understanding to communicate through varied content, media and art techniques.

Visual Arts–Historical and Global Connections

- VA.912.H.3.3 - Use materials, ideas, and /or equipment related to other content areas to generate ideas and processes for the creation of works of art.

Visual Arts–Innovation, Technology, and the Future

- VA.912.F.3.1 - Use technology applications and art skills to promote social and cultural awareness regarding community initiatives and/or concerns.
- VA.912.F.3.12 - Use digital equipment and peripheral devices to record, create, present, and/or share accurate visual images with others.

National Next Generation Science Standards

Ecosystems: Interactions, Energy, and Dynamics

- HS-LS2-7 - Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.

Earth and Human Activity

- HS-ESS3-4 - Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.

Engineering Design

- HS-ETS1-1 - Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.
- HS-ETS1-3 - Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

National Visual Arts–Creating

- VA:Cr1.2.la - Collaboratively shape an artistic investigation of an aspect of present day life using a contemporary practice of art and design.

Note: Related National Mathematics Standards and National Language Arts Standards are listed in the Florida section above.

Driving Green

Rate each group on a 1 - 10 scale (with 10 being the highest) for each of the categories. Total each groups score across.

Group # / Name	Content Knowledge	Creativity & Originality	Video Presentation Skills	Total Score
	Terms and ideas are correct and complete	Video is unique and interesting	Ideas are clearly shown	

Evaluate your own group by answering the questions below:

1. How did you make sure all group members shared in the responsibility of completing this project?

2. What issues or tasks challenged the group?

3. What went well?

4. How could you improve your group's overall performance?

Driving Green

1. At the end of 2016 in the U.S. 0.9% of the 261.8 million vehicles on the road were electric. How much CO2 did they save from being released into the atmosphere? For electricity comparison, use the calculator here: http://www.ucsusa.org/clean-vehicles/electric-vehicles/ev-emissions-tool

2. The average life of a car in the U.S. is currently 11.6 years. If 25% of the new car sales in the next 11.6 years are electric, how much CO2 could be saved per year by the fifth year? Express your answer in tons. *(For this hypothetical situation, assume that the number of cars on the road will stay static at 261.8 million and that the number of new cars bought each year is equal. Use your location information as the basis for the difference between gasoline and electric vehicle emissions)* Note: one ton of CO_2 = 1000kg

   ....if 60% of the sales were electric cars?

3. What reasons do you think some people might be reluctant to abandon their sport utility vehicles and trucks in favor of electric cars?

4. An electric car in your area is being charged by a photovoltaic array on the carport at its home location. The array is grid connected, meaning that the loads that it powers use the electricity it produces when it is sunny, but when there isn't any sunlight the loads are powered by electricity from the power plant. The electric car is plugged in at night on five days of the week, and during the daylight hours on two days of the week. How much more CO_2 (on average) is being saved by charging the car batteries with photovoltaic produced electricity over the typical battery electric car? Use the website from question 1 to obtain the grams of CO_2 per mile for a plug-in electric vehicle in your area.

5. Another electric car in your area is being charged while the owner is at work at a local parking garage that has a photovoltaic canopy. Assuming the car's owner works five days a week, how much CO_2 per mile (on average) is being saved over a plug-in electric vehicle that doesn't have access to photovoltaics?

6. What would the average grams of CO_2 per mile be for a vehicle that can be charged everyday, during the day, with photovoltaic produced electricity?