

Cruisin' the Car Show

Student Objective

The student:

- will compare currently available models of electric vehicles on cost, range and amenities
- will become familiar with how hybrids and plug-in electric cars work and learn the major components of each
- will be able to make informed decisions on what type of vehicle to own
- will work cooperatively to create a presentation that communicates information
- will calculate the monthly payments on an amortized loan

Key Words:

amortization
controller
efficiency
induction motor
inverter
regenerative braking
systems perspective
torque

Time:

1 class period for assignment
2 - 3 days homework for research
1 class period for presentations & discussion

Materials:

- internet access
- Presentation Rubric

Background Information

The total number of electric vehicles on the road worldwide is over 2 million; new registrations of electric cars hit a record in 2016 with over 750 thousand new sales worldwide, with China accounting for over one-third of the world's electric car total. In Norway, even though they have a smaller market share, one third of the cars currently being sold are electric, and in some of their cities, electric vehicles are fast becoming the majority. In the U.S., the market share of electric vehicles has been increasing every year, but over half of the EV sales took place in California.

In 2017, Volvo announced that it would be the first major car manufacturer to go all electric—every new car will be electric—in 2019. The International Energy Agency (IEA) has set a global target, agreed in the Paris climate talks, to have 30% of all new car sales be electric by 2030. Towards that goal, the United Kingdom and France have both announced that new diesel and gasoline cars will be banned by 2040.

The availability of public charging infrastructure is crucial to mass market adoption, but currently, electric cars still outnumber public charging stations by more than six to one. While the number of public chargers has grown significantly in the last five years, more are needed.

Although the cost of batteries has traditionally made electric vehicles more expensive than

gasoline vehicles, the price of lithium-ion batteries is decreasing and is forecast to continue to decrease, which should help erase any price difference.

Procedure

1. **Engage:** Show the short video *5 Reasons to Buy an Electric Car*, (listed in the Internet Sites section).
2. Lead a short discussion on the points in the video that were new information for the students (for example, instant torque and peak torque, low maintenance costs, and the efficiency comparison).
3. **Explore:** Divide the students into project teams (see ideas for project team divisions below). Explain that they will each be researching currently available electric vehicles on the basis of their purchase and operating costs and reporting their findings back to the class. Assign the teams a group of electric vehicles to research. Some suggested ways to divide the class into groups:
 - by class of vehicle (i.e. regular two-door, regular four door, minivans, sports utility, luxury).
 - have groups draw slips of paper with manufacture names on them—each group draws two or three slips
 - restrict the exercise to only plug-in electric vehicles, reducing the number of vehicles to be researched to somewhere around 3 - 4 vehicles per group (depending on how many groups you have)
 - make the discussion a bit more relevant to your class by assigning only the most popular (and affordable) models of cars currently available. A quick internet search will give you this list for your current model year
 - by manufacturer (at this writing there are 17 electric and hybrid vehicle manufacturers—so you may wish to give each group a couple of manufacturers)
For example:
 1. Audi, BMW, Buick, Cadillac
 2. Chevrolet, Chrysler, Dodge, Fiat
 3. Ford, General Motors, Honda, Hyundai
 4. Kia, Mazda, Mercedes, Mitsubishi
 5. Nissan, Porsche, Smart, Subaru
 6. Tesla, Toyota, Volkswagen, Volvo
4. Instruct the students that they can use the internet (i.e. manufacturer's websites, EPA listings, etc), sales representatives at dealerships, and new vehicle buyers guides (i.e. Consumer Reports, Kelly Blue Book, etc) to find the values needed for their comparison spreadsheets.
5. Tell the students that they will be turning in their spreadsheet, but also using the data from it to create an interesting presentation on the vehicles in their category. The target audience for their presentation is a group of recent college graduates who are thinking about buying an electric car. They should make their presentation interesting, convincing, and 'sell' their cars, using data from their research.
6. Help the students as needed with their research and completing their spreadsheets.

Procedure (presentation day)

1. **Explain:** Title three areas of the board with “Efficiency/Emissions”, “Cost” and “Group Favorite”. As each group gives their presentations, they should list their top vehicle in each category on the board with its efficiency rating and/or cost, and under Group Favorite list the vehicle that they most wanted to own.
2. As each group gives their presentation, the other groups should rate them on the Presentation Rubric.
3. **Explain / Elaborate:** Lead a discussion on how the results of the three rankings differ. What factors determined the relative popularity of the different models? Is it realistic to expect people to make efficiency their top priority when buying a vehicle? What other things do people consider?

Answer Key (Laboratory Manual)

- 2 - 4. Answers will vary depending on which vehicles the student researched, however, they should show an understanding of the range of the cars they researched, and how that translates into practical situations. They also should suggest alternative ideas (i.e. renting a car for the twice yearly trip with the money saved from not buying gasoline, adding more charging stations along major roadways, etc)

Answer Key (Problem Set)

- 1 - 2. Answers will vary depending on the vehicle selected, however, the student should show an understanding of how to compute the annual and weekly fuel costs.
3. Answers will vary depending on the vehicle selected, however, students should show their work and the ability to accurately use a formula to obtain the value.
- 4 - 6. Students should show an understanding that although leasing a vehicle costs less than payments, you don’t actually own the vehicle; however, for those who don’t travel over the allotted miles per year or those who prefer to have a new car and not have to worry about car repairs, a lease may be a good option.

Key Words & Definitions

- **amortization** - repayment of a loan principal over time, usually by equal payments
- **controller** - a device that regulates the amount of power that goes to the electric motor
- **efficiency** - the ratio of useable energy coming out of a process to the total energy being input into a process
- **induction motor** - an alternating current motor in which torque is produced by the reaction between a varying magnetic field (generated in the stator) and the current (induced in the coils of the rotor)
- **inverter** - a device that converts direct current into alternating current
- **regenerative braking** - an energy recovery mechanism which slows a vehicle or object by converting its kinetic energy into a form which can be used (either stored by a battery or used immediately)
- **systems perspective** - taking into account all of the behaviors of a system as a whole in the context of its environment

- **torque** - a measure of how much a force is acting on an object to cause rotation

Related Research

1. Explore what scientists and researchers think is the future of transportation 50 years from now and 100 years from now.
2. Research design features that could increase a car's efficiency. Make an annotated drawing of a 'future car' that maximizes the car design for efficiency.
3. Research the macro-trends in car design. Why do the majority of vehicles resemble each other? Speculate what causes the trends in car design that makes the public desire a specific type, shape, style, or color of vehicle.
4. Analyze new car advertising, looking closely at the styles of hair, clothing and people, colors and graphic styles used, background music, style of videography, as well as what is actually being said in the ad. What aspects of the vehicles are the car manufacturers advocating? What demographic are they targeting? Using your observations, give a presentation that includes a gallery of ads that each target a different age, sex, and economic group, explaining to your audience what the advertising is subtly (or not so subtly!) doing.

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 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:

<https://www.youtube.com/watch?v=ysHpmrwsEsY>

5 Reasons To Buy An Electric Car, video produced by Engineering Explained, explains the pros of owning an electric car in driving performance, maintenance, efficiency, convenience of charging and price.

<https://www.youtube.com/watch?v=36H9BVeMYMI>

Why do Electric Cars Only Have 1 Gear, video produced by Engineering Explained as part of a 5 video series (links to the others were not available at the time of printing but can be found on their site). This series is great for your car enthusiasts, race car fans, future engineers and those who love to know how things work.

<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 the CO₂ emissions (from the power plant) in your area for that vehicle and how that compares to the national average.

<https://www.youtube.com/watch?v=3SAxXUIre28>

Detailed explanation of how an electric car and an induction motor work using animations of a Tesla S car.

<https://energy.gov/eere/videos/energy-101-electric-vehicles>

U.S. Department of Energy video, *Energy 101: Electric Vehicles*, is an introduction to electric and hybrid vehicles.

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

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

Internet Sites (vehicle information):

<https://pluginamerica.org/>

Plug In America's site includes information about current plug-in electric vehicles, including a comparison chart, charging maps, and information to help new electric vehicle owners.

<http://www.caranddriver.com/>

Car and Driver, respected new car reviews.

<https://content.sierraclub.org/evguide/>

Sierra Club Electric Vehicle Guide includes good information on pollution avoided, gasoline and maintenance savings.

<http://www.hybridcars.com/>

Respected site with car reviews, buyers guides, forums and news.

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

Group #	Professional Presence	Language Skills	Subject Knowledge	Visual Aids	Total
	eye contact, poise, body language	vocabulary & word usage, understandable	not read word for word, knows subject	photos, etc	

Evaluate your own group by answering the following questions:

1. Did all members of the group have an equal responsibility? How did you make sure that all members shared in the completing of this project?

2. What was the hardest part of this project?
3. What did you enjoy most about this project?
4. Did your group have a hard time deciding on which vehicle was your 'group favorite'?

Cruisin' the Car Show

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																		
Life Science																					
Standard 17	SC.912.L.17.															X		X			
Mathematics Standards		MAFS.912.N-Q.1.1, MAFS.912.A-REI.1.2, MAFS.K12.MP.1.1, MAFS.K12.MP.2.1																			
Language Arts Standards		Grades 9 & 10: LAFS.910.W.3.7, LAFS.910.SL.1.1, LAFS.910.SL.1.2, LAFS.910.SL.2.4, LAFS.910.SL.2.5 Grades 11 & 12: LAFS.1112.W.3.7, LAFS.1112.SL.1.1, LAFS.1112.SL.1.2, LAFS.1112.SL.2.5																			

Standard 1: The Practice of Science

- SC.912.N.1.4 - Identify sources of information and assess their reliability according to the strict standards of scientific investigation.

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.

Standard 17: Interdependence

- SC.912.L.17.15 - Discuss the effects of technology on environmental quality.
- SC.912.L.17.17 - Assess the effectiveness of innovative methods of protecting the environment.

Mathematics Standards**Number & Quantity: Quantities**

- MAFS.912.N-Q.1.1 - Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas.

Algebra: Reasoning with Equations & 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.

Mathematical Practice

- MAFS.K12.MP.1.1 - Make sense of problems and persevere in solving them.
- MAFS.K12.MP.2.1 - Reason abstractly and quantitatively.

Language Arts Standards

Writing Standards

- LAFS.910.W.3.7 & LAFS.1112.W.3.7 - Conduct short as well as more sustained research projects to answer a question or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

Standards for Speaking and Listening

- LAFS.910.SL.1.1 & LAFS.1112.SL.1.1 - Initiate and participate effectively in a range of collaborative discussions with diverse partners on grades 9 - 10 (11 - 12) topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively.
- LAFS.910.SL.1.2 & LAFS.1112.SL.1.2 - Integrate multiple sources of information presented in diverse formats and media in order to make informed decisions and solve problems, evaluating the credibility and accuracy of each source and noting any discrepancies among the data.
- LAFS.910.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.

National Next Generation Science Standards

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-ETS1-3 - 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.

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

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1. Create a spreadsheet for the vehicles in your assigned category. Use the template below as a guide, **using as many columns as needed for the number of vehicles you research**. Your group should research all of this year's models in your category.

	Vehicle A	Vehicle B
Vehicle Data		
Make/Model		
Type (all electric or hybrid)		
# of passengers		
motor size (kW)		
horsepower		
battery size / type		
range (electric)		
efficiency (fuel consumption) MPGe		
acceleration (0 - 60) / top speed		
standard amenities		
Retail base price		
CO₂ Emissions		
Upstream CO ₂ emissions per kWh		
Annual upstream CO ₂ emissions		
Hybrid only: Annual gas & elec CO ₂ emissions *		
Savings		
yearly savings over gasoline *		
yearly CO ₂ emission savings over gas *		

* for all problems, assume a gasoline price of \$3.00 a gallon, electricity cost of 12 cents a kWh, a yearly driving average of 18,000 miles, CO₂ emissions for an average gasoline vehicle at 20 lbs CO₂ per gallon of gas, and an average of 35 mpg

Given each family scenario below, speculate which car would be the best. If there is currently not a good choice, what are some of the things that can be done to improve the situation (new car models, new infrastructure, new human habits?)

2. Family of four that takes two vacations to the beach (300 miles away) each year and commutes 25 miles (one way) from their home in the suburbs to work.

3. Married couple with one car, sharing it for the commute to two different jobs, up to 35 miles per day. The family's income is less than 50,000 per year.

4. Family who lives in rural America with no commute, but must travel 40 miles each way to buy groceries and household items.

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Use one of the vehicles you researched in this lesson for the questions below.

The vehicle you are using for these questions is (year, make & model):

1. Compute the annual fuel costs assuming 12 cents per kWh for electricity and 18,000 miles traveled a year.
2. What is the weekly fuel (electricity) cost for this vehicle?

Determine the monthly payment on a 5 year loan for the car chosen above. Use the list price of the vehicle as your starting point, but be sure to add the sales tax! You were lucky to be able to get a good loan through your parent's credit union (with them cosigning the loan). Your annual interest rate is only 5%

List price _____

Sales tax _____

Interest rate: 5%

To calculate the monthly payments, use the formula for loan amortization (amortization means paying down the loan in equal installments)

$$A = \frac{P \cdot r}{1 - (1 + r)^{-n}}$$

A = the monthly payment

P = the principal (your cost above plus the sales tax)

r = the interest rate per month; which is **Monthly rate = $(1 + \text{annual rate})^{1/12} - 1$**

n = the total number of months

3. What would your monthly payment be? Show your calculations (continue on back as needed)

4. Research online what is the current monthly payment to lease the vehicle you have chosen. Why do you think it costs less per month to lease the vehicle?
5. What are the advantages of leasing a vehicle?
6. What are the disadvantages of leasing a vehicle?