Roadtrip!

Student Objective
The student:
- will be able to explain what infrastructure changes are necessary to completely transition to electric vehicles
- will plan a long distance trip via an electric vehicle, calculating mileage and recharging stops
- will know how to find electric recharging stations
- will work cooperatively to create a presentation that communicates information.

Key Words:
DC fast charging
infrastructure
itinerary
level 1 charging
level 2 charging
on board charger

Time:
1 class period for assignment
1 - 2 days homework or classwork (research)
1 class period for presentations & discussion

Materials:
- internet access
- 6-sided dice
- Presentation Rubric

Background Information

Ninety five percent of electric car charging is done at home. It is convenient–you spend 2 to 3 seconds to plug in your car, leave it overnight, spend another 2 to 3 seconds unplugging and you are ready to go. Home charging can be done by simply plugging into a standard electric outlet; all electric cars have an 'onboard charger' that can accomplish this. However, this method is slow, adding only about 4 miles of range for each hour of charging. For faster home charging you can use an EVSE (Electric Vehicle Service Equipment) charger. An EVSE is a dedicated charger that sends a higher level of current to the car's onboard charger. Different models of electric cars have different onboard chargers and different rates of charge that can be obtained. These charge rates currently range from 11 miles per hour up to 29 miles per hour. EVSEs can be used at home, but are also found at public charging stations where they are known as level 2 chargers.

Public charging stations are even more diverse. They vary on charge rate, charging ports, charging 'network' and the rates that you pay (or not). **Level 2 chargers** are common at charging stations, especially at places of work, shopping centers, or places where people will park for a period of time. These provide power at 220v (up to 30amps), at a rate of 10 - 25 miles of range per hour of charge. **DC fast chargers** provide DC electricity to the battery instead of using the car's onboard converter to change the current. This makes the charging faster, at a rate of 60 - 80 miles in 20 minutes; however, these are currently less common at public charging

stations. Tesla also has their own network of charging stations that use **Tesla Supercharging** which has a power output of 120 kW which can charge at a rate of 170 miles in 30 minutes.

Another thing that must be kept in mind is what type of charging connector is available at the station and what port(s) are in your vehicle. All modern electric vehicles have the SAE J1772 standard receptacle for level 1 or level 2 charging. Most (but not all) plug-in electric vehicles also have the CHAdeMO connector for DC fast charging. Currently, a hybrid connector that adds high-voltage DC power to the typical J1772 connector is being worked on; when rolled out, it would enable all vehicles to use the same connector for all levels of charging.

Charging stations may not be readily visible–they may be at the back of a parking lot or behind a building. Because of this, several apps are available (i.e. PlugShare, EV Charge Hub & ChargePoint) to help you locate the charging stations in any area.

Another thing to realize is that the rate of flow of electricity into the batteries tapers off as the batteries fill. At the beginning of the charging cycle, the electricity can flow at a rapid rate. When the batteries reach about 50% of charge, you will notice a slowing, to the point that at 80% of charge it becomes so slow that most people stop there and continue on their way. In fact, some charging stations will actually cut you off at 80% charge.

Procedure

1. **Engage:** Show the video *Driving an Electric Car Cross Country in a Snowstorm* (link listed in Internet Sites section)
2. Let the students discuss the video. Some of the things the students might want to talk about (besides the snow and the snowflake on the dash display!):
    - the car costs him the same amount as what he is currently spending on gasoline - a ‘free’ car
    - the difference between the high charge CHAdeMO charger, and the level 2 J1772 charger
    - the importance of paying attention to the charge level of the vehicle all the time
    - when he charged at the ABB site, it was quick (and free) versus the slower chargers
3. Divide students into working groups of a maximum of four students per group.
4. **Explore:** Tell the class that each group will plan an imaginary field trip using the criteria in the introductory letter in the Laboratory Manual. The goal is to plan the ‘best’ field trip, starting and returning to a location of their choice in the contiguous United States. However, the group will decide for themselves what constitutes the ‘best’ trip–it could be the trip with the best places to visit, the most places to visit, the most scenic roadways, the best restaurants, most famous people to visit, or anything they want to make it.
5. Each group will present their trip to the group. The group’s photos will be used during the presentation, and each group will also explain any problems that they encountered planning the trip with their electric vehicle, and what they did during charging stops.
6. And because things in real life never go as smoothly as planned, each group will roll a die during their presentation at the beginning of their description of each day of their trip. They will need to integrate any new ‘problems’ encountered into their day. The outcomes of the dice rolls are:

A roll of--

- 1 - After lunch you encounter a huge rain storm. This causes an extra drain on your batteries that equals 5 miles of charge.
- 2 - No problems. Clear driving weather and 'lady luck' is with you!
- 3 - The charge station you planned on stopping at in the afternoon is closed or inoperable. You must go to another charging station.
- 4 - The fast charger you planned on using is not available (or not accessible). You must use the slower charger.
- 5 - Great weather, not much traffic. You make good time and use 10 miles less charge on your batteries than expected.
- 6 - There is a large construction detour that you hadn't expected on the route you chose for the morning leg of your trip. The traffic is heavy, and the delays and the increased length of this part of the trip causes an extra drain on your batteries equal to 10 miles of charge.

7. Everyone will rate the other groups' presentations using the Presentation Rubric.

Procedure (presentation day)

1. As each group gives their presentation, the other groups should rate them on the Presentation Rubric.
2. **Explain:** Make sure that each group tells how many miles occur between charging stops, what kind of charger is used, how long they take to charge the vehicle and how much it costs them.
3. **Extend / Elaborate:** After the presentations are completed, lead a discussion. Some of the points you may want to cover are:
   - trips they liked the best and why
   - which presentation was the most interesting and why
   - which car seemed the easiest to drive long distance and why
   - what needs to be done to our infrastructure to make long distance electric car travel easier
   - what needs to be done to the electric cars themselves to make long distance travel easier

Answer Key

1. Answers will vary depending on which vehicle is chosen, however, the student should show an understanding of the factors that determine how long the car of their choice needs to charge, how many kW the car needs to charge**.**

2 - 4. Answers will vary, but although the rental car may be more expensive, the student should recognize that in some situations (such as vacations or camping) people may choose to rent a vehicle, and that occasional vehicle rental may actually help them have an electric vehicle for their day-to-day transportation–and save them money over the whole year.

Key Words & Definitions

- **DC fast charging** - enables rapid charging at heavy traffic public fueling stations at a rate of 60 - 80 miles in 20 minutes
- **infrastructure** - the underlying foundation or framework. In the case of electric cars this includes the charging stations**.**
- **itinerary -** a planned route or journey
- **level 1 charging** - uses a plug and a standard household (120v) outlet and provides about 4 miles of charging range per hour
- **level 2 charging -** uses a dedicated device–an EVSE–to provide power at 220v and up to 30amps. This can add 10 - 25 miles of range an hour.
- **on board charger** - factory installed into the vehicle, it converts AC wall power to DC electricity for the battery

Related Research

1. Create a recreational pamphlet of places to see and things to do in your area. Include mass transit information as well as available public charging stations.

Related Reading

- ***Off The Grid: My Ride From Louisiana to the Panama Canal in an Electric Car*** by Randy Denom (Skyhorse Publishing, 2017)
  Only a week after the nation's newspapers ran stories of the first cross-country electric car trip, Randy Denom and his friend Dean Lewis quietly crossed the Rio Grande in south Texas in an attempt to drive a Tesla S across seven (sometimes inhospitable) countries to Panama City. This is a very entertaining, easy read that will hook students on the adventure.

Internet Sites:

https://www.youtube.com/watch?v=idndjjFZzxY
Driving an Electric Car Cross Country in a Snowstorm, video author buys an electric car and drives it home in a snowstorm.

https://www.youtube.com/watch?v=ETmaM9jEzNs
What Happens When You Attempt a UK Road Trip in an Electric Car?, CNET video traveling the country roads of Great Britain shows the need for more infrastructure as well as showing how pleasant driving an electric car can be.

https://chargehub.com/en/charging-stations-map.html
Charge Hub map of public charging station

https://itunes.apple.com/us/app/plugshare/id421788217?mt=8
Charging station locator map for Apple

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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 #	Presentation Skills	EV Charging	Itinerary	Visual Aids	Total
	Eye contact, Poise, Body language	Charging knowledge	Interesting? Quality of plan	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 distribute the assignment among team members? Did everyone contribute to the ideas for the stops on the trip?

2. What was the hardest part of the project?

3. What did you enjoy most about this project?

4. Would you enjoy taking the trip you planned? Why or why not?

Roadtrip!

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 4	**SC.912.N.4**		**X**																		
Energy																					
Standard 10	**SC.912.E.6.**	**X**																			
Life Science																					
Standard 17	**SC.912.L.17.**																**X**				
Language Arts Standards		**Grades 9 & 10:** LAFS.910.W.3.7, LAFS.910.SL.1.2, LAFS.910.SL.2.4, LAFS.910.SL.2.5, LAFS.910.L.3.6 **Grades 11 & 12:** LAFS.1112.W.3.7, LAFS.1112.SL.1.2, LAFS.1112.SL.2.4, LAFS.1112.SL.2.5, LAFS.1112.L.3.6																			

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 10: Energy

- SC.912.P.10.1 - Differentiate among the various forms of energy and recognize that they can be transformed from one form to others.

Standard 17: Interdependence

- SC.912.L.17.16 - Assess the effectiveness of innovative methods of protecting the environment.

Language Arts

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.1.2 & 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 & LAFS.1112.SL.2.4 - Present information, findings, and supporting evidence conveying a clear and distinct perspective, such that listeners can follow the line of reasoning, alternative or opposing perspectives are addressed, and the organization, development, substance, and style are appropriate to purpose, audience, and task.
- LAFS.910.SL.2.5 & LAFS.1112.2.5 - Make strategic use of digital media in presentations to enhance understanding of findings, reasoning, and evidence and to add interest.

Language Standards

- LAFS.910.L.3.6 & LAFS.1112.L.3.6 - Acquire and use accurately general academic and domain-specific words and phrases, sufficient for reading, writing, speaking, and listening at the college and career readiness level; domonstrate independence in gathering vocabulary knowledge when considering a word or phrase important to comprehension or expression.

National Standards

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

Roadtrip!

(*Note: Sorry, this prize is totally imaginary....*)

Dear Researcher,

Congratulations! Your team has been selected to receive a free trip in a plug-in electric vehicle. A generous anonymous sponsor has agreed to pay for your food, lodging, and spending money! You will also have use of your choice of a brand new plug-in electric car (4 seater).

Your sponsor has established a few rules you must follow:

a. You may only spend $15. total on electricity (you will receive a card that works on all of the types of electric chargers). You may not use any of your personal money on this or any other part of your trip. If you run out of money for electricity before you get home you will have to walk home.
b. Your sponsor wants to receive a photo from each place that you visit.
c. You should see as many sights as you can, but your visit at each place cannot be less than one hour (charging stations not at a sightseeing stop are excluded).
d. You must adhere to the speed limits. To help you schedule your trip, use an average of 65 miles an hour for interstate roads, 55 miles an hour for U.S. highways, and 45 miles an hour for all other roads.
e. Get plenty of rest. You must sleep at least eight hours a day in order to stay sharp enough to drive a car.
f. Keep your body strong. Plan to stop for 30 minutes each day for breakfast, an hour for lunch, and an hour for dinner. Take-out is not allowed, and eating and drinking in your vehicle is not allowed. The sponsor wants you to fully enjoy your meals and concentrate on the road when you are traveling.
g. Assume refueling stations are open from 9am to 6pm.

It's Monday morning at 8:00am. Your car is fully charged and is ready to roll. Have fun!

Notes to help you plan your trip:

Public charging stations have several different types of chargers.

- **Level 2 chargers** are common at charging stations, especially at places of work, shopping centers, or places where people will park for a period of time. These provide power at 220v (up to 30amps), at a rate of 10 - 25 miles of range per hour of charge.
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Another thing that must be kept in mind is what type of charging connector is available at the station and what port(s) are in your vehicle.

- All modern electric vehicles have the SAE J1772 standard receptacle for level 1 or level 2 charging.
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Charging stations can be located by using one of the available apps (i.e. PlugShare, EV Charge Hub & ChargePoint).

Another thing to realize is that the rate of flow of electricity into the batteries tapers off as the batteries fill. At the beginning of the charging cycle, the electricity can flow at a rapid rate. When the batteries reach about 50% of charge, it slows and by the time it reaches 80% of charge it becomes so slow that most people stop there and continue on their way. In fact, some charging stations will actually cut you off at 80% charge. We expect you to end your charging at public (not overnight) charging stations at the 80% point.

You will need to research the charging capacity and speed of charging of the vehicle your group chooses, and plan your time and stops to match your vehicle.

If you choose a charging station that does not list cost information, use $2.50 per hour of charge regardless of type of charger.

And because things in 'real life' never go as smoothly as planned, each group will roll a die during their presentation at the beginning of their description of each day of their trip. You will need to integrate any new 'problems' encountered into your day. The outcomes of the dice rolls are:

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6 - There is a large construction detour that you hadn't expected on the route you chose for the morning leg of your trip. The traffic is heavy, and the delays and the increased length of this part of the trip causes an extra drain on your batteries equal to 10 miles of charge.

Assume that you receive your car with a full charge, and you can return it empty if you wish!

Roadtrip!

Use the vehicle you used in this unit for the questions below.

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

1. Your family (four people) is planning a vacation to the state park that is 150 miles away. There is a public charging station on the route that you could stop and recharge. They charge $3.50 per hour for a charge on the DC fast charger, and the state park where you are going has a flat $0.50 fee for each hour you charge at their level 2 charger. Assuming that your electricity cost at home is 12 cents a kWh, and you charge fully before starting out, how much would the round trip cost you?

2. Would renting a car at $84. for the weekend be cheaper?

3. What reasons might you have for wanting to rent a vehicle?

4. What reasons might you have for wanting to drive your electric car?