Today I Learned About Electric Cars

Description:

Electric vehicles (EVs) hold great promise for a lower-emissions future – but just how much promise? Students investigate the emissions associated with EV use in different parts of the US. Then, they learn about the air pollution impacts of gas and diesel vehicles and design a communication project to reduce exposure at school.

Skills & Objectives

SWBAT

- Connect the way that electricity is produced with the carbon dioxide impact of an electric vehicle.
- Explain the connection between gas and diesel vehicles and air pollution and describe some solutions.
- Design a communication project to effect change in their school.

Skills

- Map reading
- Data analysis
- Communication

Students Should Already Know That

- Electricity is generated in a variety of ways, some of which produce high amounts of carbon dioxide, while others produce small amounts.

Standards Alignment:
HS-ESS3-4 Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.
HS-ETS1-3 Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs.
RST.11-12.7 Integrate and evaluate multiple sources of information presented in diverse formats and media in order to address a question or solve a problem.

Disciplinary Core Ideas:
ESS2.D Weather and Climate
ESS3.D Global Climate Change
ETS1.B Developing Possible Solutions

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How To Use These Activities:

Pages with the circular "TILclimate Guide for Educators" logo and dark band across the top are intended for educators. Simpler pages without the dark band across the top are meant for students.

Each of the included activities is designed to be used as a standalone, in sequence, or integrated within other curriculum needs. A detailed table of contents, on the next page, explains what students will do in each activity.

A Note About Printing

All student pages are designed to be printable in grayscale, except for the flags on page 6. A few copies of this page could be printed color for students to share, or the image projected in the classroom.

The worksheets do not leave space for students to answer questions. Students may answer these questions in whatever form is the norm for your classroom – a notebook, online form, or something else. This allows you, the teacher, to define what you consider a complete answer.

Podcasts in the Classroom: Throughout these Guides for Educators, we invite students to think about how they would share their learning with family and friends. One way to do this is to encourage your students to create their own podcasts - they're shareable, creative, and have multiple options for embedded assessment. We would love to hear any podcasts or see any other projects you or your students create! Email us at tilclimate@mit.edu, Tweet us @tilclimate, or tag us on Facebook @climateMIT.

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Detailed Table of Contents

For more activities about the electric grid, see the Electric Grid and Climate Change Educator Guide https://climate.mit.edu/til-about-electric-grid-educator-guide.

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Electric Vehicles

This Educator Guide includes two data investigations, a communication project, and a discussion. Educators may pick and choose among the pieces of the Guide, as suits their class needs.

Parts of this Guide may align with the following topics:

- Physical science: Atmospheric chemistry, fossil fuels, and electric motors.
- Life/environmental science: Impacts of cars on the environment and human health.
- History/social science: History of electric vehicles, human health impacts of cars.
- ELA/literature: Connections to futuristic science fiction, imagining future transportation.
- ELA/nonfiction: Communication projects, identifying audience and platform.

MIT Resources

We recommend the following as resources for your own better understanding of climate change or as depth for student investigations. Specific sections are listed below:

- Climate Science, Risk & Solutions, an interactive introduction to the basics of climate change. https://climateprimer.mit.edu/
  - Chapter 02
  - Chapter 08
  - Chapter 10
- MIT Climate Portal Explainers are one-page articles describing a variety of climate topics. New Explainers are posted monthly. https://climate.mit.edu/explainers
  - Greenhouse Gases
  - Renewable Energy
  - Cities and Climate Change

Car and Driver Magazine has an overview of the history of electric vehicles https://www.caranddriver.com/features/g15378765/worth-the-watt-a-brief-history-of-the-electric-car-1830-to-present/

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Wrap-Up Discussion Questions

- What percentage of your electricity comes from low- or no-CO_2 sources?
- Given this, how do you think your CO2 emissions from electricity compare to other regions?
- Do you think there is any place in the US where an all-electric vehicle produces as much or more CO_2 than does an all-gas vehicle? How much variation is there across the US?
- How could our school help protect students, teachers, and staff from air pollution?
- Are you excited about electric vehicles? Why or why not?
- What problems could electric vehicles solve? Which problems do they not solve?
- What surprised you about electric vehicles? What questions do you still have?

Climate Solutions

Climate solutions can be thought of as falling into four categories outlined below. Across all categories, solutions at the community, state or federal level are generally more impactful than individual actions. For example, policies that increase the nuclear, solar and wind mix in the electric grid are generally more effective at reducing climate pollution than asking homeowners to install solar panels. For more on talking about climate change in the classroom, see “How to Use This Guide”.

- **Energy Shift**
  How do decision-makers make the switch from carbon-producing energy to carbon-neutral and carbon-negative energy?
- **Energy Efficiency**
  What products and technologies exist to increase energy efficiency, especially in heating and cooling buildings?
- **Adaptation**
  How can cities and towns adapt to the impacts of climate change?
- **Talk About It**
  Talking about climate change with friends and family can feel overwhelming. What is one thing you have learned that you could share to start a conversation?

What solutions are the most exciting in your classes? We would love to hear from you or your students! Images, video, or audio of student projects or questions are always welcome. Email us at tilclimate@mit.edu, Tweet us @tilclimate, or tag us on Facebook @climateMIT.

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"An electric vehicle is only as green as the electricity that goes into it. Those emissions could be zero or nearly zero if that electricity is coming from renewables, such as solar and wind. But on the U.S. electricity grid today, we have a lot of gas and some coal and other things as well."

Prof. David Keith, MIT Sloan School of Management
TILclimate podcast: Today I Learned About Electric Cars

How Low-Carbon is an Electric Vehicle?

As Prof. Keith says in the podcast episode, the emissions from driving an electric vehicle vary depending on how the electricity is produced. Electricity produced from coal, oil, natural gas, and biomass all produce carbon dioxide (CO_2). Without carbon capture, this carbon dioxide enters the atmosphere, where it acts like a blanket, trapping heat. Trapped heat is changing Earth's climate, leading to more intense storms, droughts, and other weather events.

USEPA eGRID subregions, January 2022 https://www.epa.gov/egrid/power-profiler#/

Overall, the US produces about 62% of its electricity from carbon-dioxide-producing sources such as natural gas and coal.[1] The rest is produced from low- or no-carbon sources such as nuclear, wind, and hydropower. (For more on power sources, see page #). The US electric grid is divided into 27 eGRID regions, each of which produce their own electricity (although there is some trade between regions). Each of these regions produce their electricity differently, depending on resource availability, infrastructure, and historical and political decisions.

1 USEPA eGRID Data Explorer, 2020 data https://www.epa.gov/egrid/data-explorer

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Where Does Your Electricity Come From?

1. Visit https://www.epa.gov/egrid/data-explorer
2. From the map, determine which eGRID subregion you live in. (If it is unclear on the map, type in your ZIP code at https://www.epa.gov/egrid/power-profiler#/ to find your subregion.)
3. From the drop-down menus at the top, select "I want to explore **resource mix (%)** for **total generation** for **all fuels** at the **eGRID subregion** level for [choose the most recent year available]."

Observe

How much difference is there among subregions? What factors do you think affect this?

4. Click on your subregion so that it becomes highlighted.
5. On the right side of the screen, the resource mix for your subregion and the US overall are displayed. Write these numbers into the columns provided on page 4.

Analyze

What percentage of your electricity comes from low- or no-CO_2 sources?

How do you think this affects CO_2 emissions from electricity in your subregion?

Do you think your subregion is higher or lower than the US average?

6. From the drop-down menus at the top, change to "I want to explore **output emission rates (lb/MWh)** for **CO_2equivalent**[1] for **all fuels** at the **eGRID subregion** level for [choose the most recent year available.]"
7. On the right side of the page, click **Sort by Amount**.

Observe

Where does your subregion fall in the list of CO_2e[1] emissions rates?

Extend

How else could you use this tool to explore the topic of electricity and emissions?

1 One carbon dioxide equivalent, or CO2e, is the amount of heat an equal amount of CO_2 would be expected to trap over the next 100 years.

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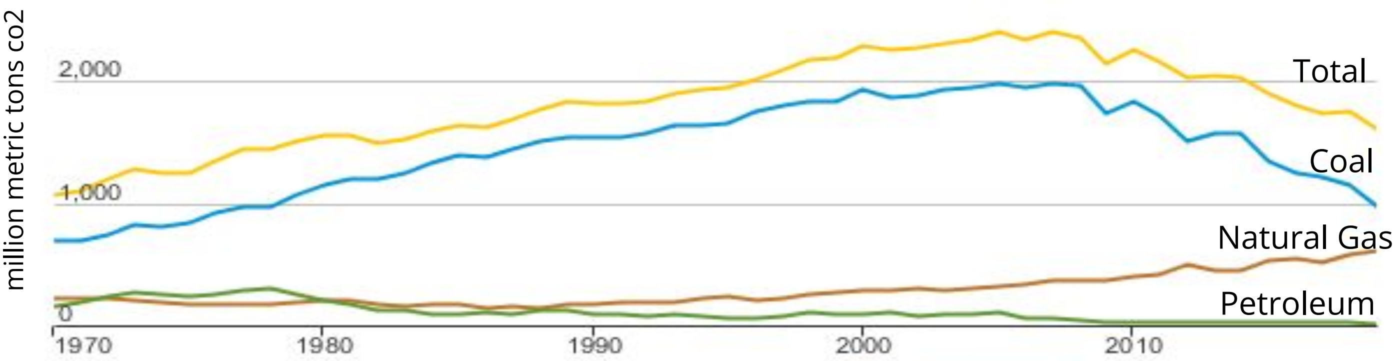
How Has Electricity Generation Changed?

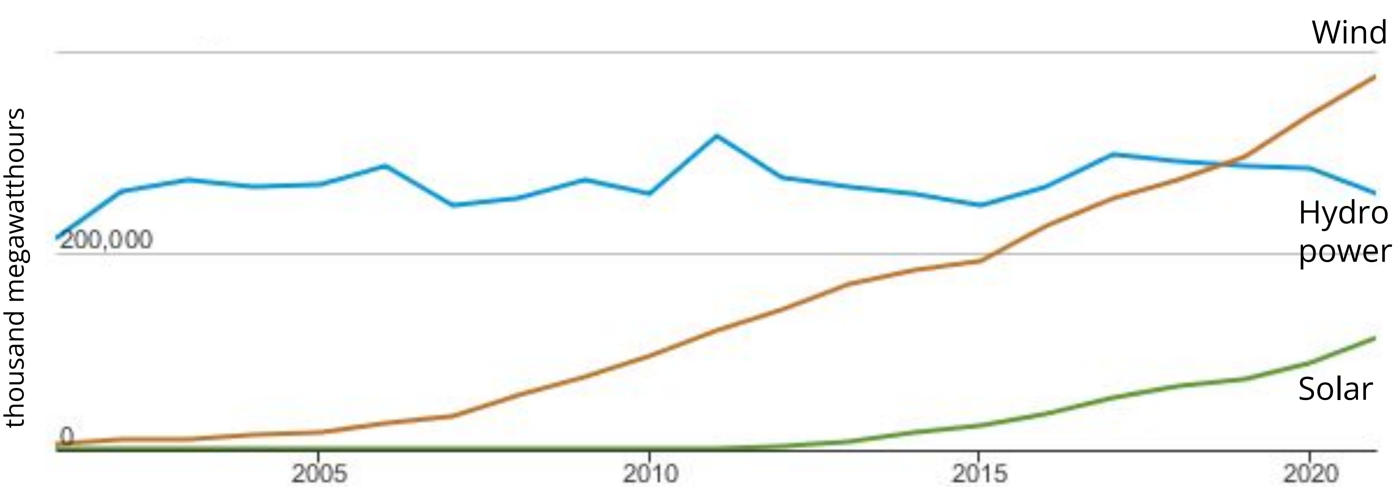
Since its peak in 2007, the amount of carbon dioxide emitted from electric power generation has fallen, from around 2.4 billion to around 1.6 billion metric tons per year.



Observe

What has changed in that time to cause this drop in emissions?

Since 2001, wind and solar power (at the utility scale) has grown steadily, from around 7.2 million to around 492 million megawatthours per year.



Analyze

What does this change in how electricity is generated mean for the future of electric vehicles?

All graphs from the US Energy Information Administration, https://www.eia.gov/beta/states/data/dashboard/electricity

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Definitions

Energy Source	Where it comes from and how it is used	US Electric Grid	My Electric Grid	Renew-able	Low CO_2
Natural Gas	Pumped from deposits underground. Refined & burned to create steam for electricity or used directly to create heat.			✗	✗
Petroleum /Oil	Pumped from deposits underground. Refined into oil, diesel, and gasoline and burned for electricity, heat, and transportation.			✗	✗
Coal	Mined and burned to create steam for electricity or used directly to create heat.			✗	✗
Nuclear	Uranium is mined and refined. Atoms are split to create heat and steam to generate electricity.			✗	✓
Biomass	Burning trees, plants, and other organic matter for heat or to generate electricity.			✓	✗
Wind	Using wind power to turn a turbine and generate electricity.			✓	✓
Hydro-power	Using flowing water to turn a turbine and generate electricity.			✓	✓
Solar	Materials mined from underground are used to capture light from the sun and generate electricity			✓	✓
Geo-thermal	Using the natural heat and water below Earth's surface to heat & cool buildings or generate electricity.			✓	✓

Renewable: Energy from sources we cannot run out of. Some types of renewable energy, like wind and solar power, come from sources that are not depleted when used. Others, like biomass, come from sources that can be replenished.

Low CO_2: Most kinds of renewable energy are also "carbon-free": they do not emit CO_2 or other greenhouse gases into the atmosphere. Biomass is renewable but burning plant matter releases CO_2. Nuclear power is carbon-free, but we do not have a renewable source of uranium.

Images from the Noun Project Becris, Koson Rattanaphan, Hamel Khaled, Nawicon, ArmOkay, Jacqueline Fernandes, Tom Fricker, Ivan, Eragon, Ben Davis, Monkik, and Charif Deffa

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“An electric vehicle running on coal has the fuel economy equivalent in the order of about 50 to 60 miles per gallon. So, the dirtiest electric vehicle looks something like our best gasoline vehicles that are available today.”
Prof. David Keith, MIT Sloan School of Management
TILclimate podcast: Today I Learned About Electric Cars

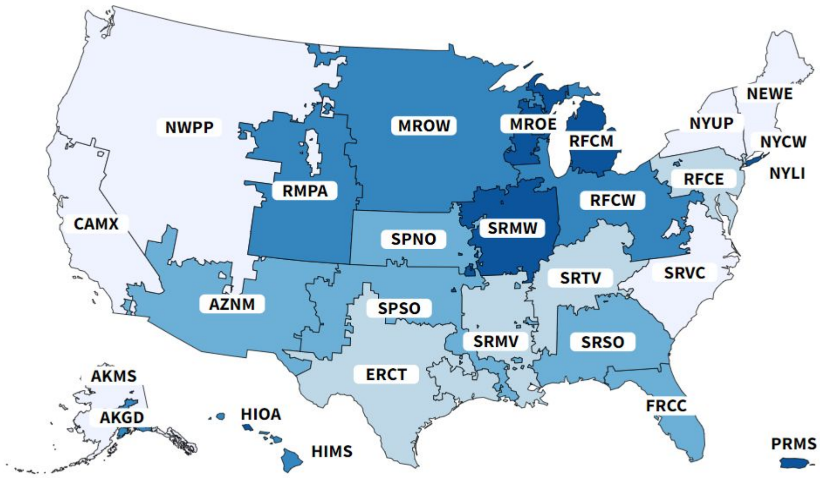
Fuel Efficiency

As Prof. Keith said in the podcast episode, "an electric vehicle is only as green as the electricity that goes into it." Electricity produced from coal, oil, natural gas, and biomass all produce carbon dioxide (CO_2). Without carbon capture, this carbon dioxide enters the atmosphere, where it acts like a blanket, trapping heat. Trapped heat is changing Earth’s climate, leading to more intense storms, droughts, and other weather events.

The CO_2 impact of a gas-powered vehicle is the same wherever it is driven, while the CO_2 impact of an all-electric vehicle varies by how the electricity is produced. The US Department of Energy rates the best and worst fuel-efficiency in vehicles each year (see table to the right). For electric vehicles, they calculate a “miles per gallon equivalent” (MPGe) based on a national average of CO_2 emissions from electricity. (The range in each category reflects the differences between larger and smaller vehicles.)

Vehicle Type	“Best” Range of MPG(e)
All-gas	25-37
Hybrid	36-59
All-electric	70-132

Regional Difference in EVs



CO_2 total output emission rate (lb/MWh) by eGRID subregion, 2020.
USEPA eGRID Data Explorer https://www.epa.gov/egrid/data-explorer

Each region’s electric grid sources electricity from a different mix of gas, coal, nuclear, hydropower, solar, wind, and other sources. By looking at the mix of these sources, you can see why some subregions have higher CO_2 emissions than others.

1 2022 Most and Least Fuel-Efficient Trucks, Vans, and SUVs https://fueleconomy.gov/feg/best/bestworstEPAtrucksNF.shtml

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How Efficient is an EV in My State?

1. Visit https://afdc.energy.gov/vehicles/electric_emissions.html
2. Click "Choose a State" and click on the map to choose your state.

Observe

How do all-electric, plug-in hybrid, hybrid, and gasoline cars compare in your state?

3. Hover over each bar on the chart to collect the exact number of pounds of CO_2 equivalent[1] produced by driving each kind of car.

Analyze

In your state, the CO_2e of an all-electric vehicle is what percent of the CO_2e of an all-gas vehicle?

4. Visit https://www.epa.gov/egrid/data-explorer. To the right of the default map, click "Sort by Amount" to show the total CO_2 emissions for each electric grid subregion in the US.
5. Choose a state within one of the regions with the highest CO_2 emissions, and a state within one of the regions with the lowest CO_2 emissions.
6. Return to https://afdc.energy.gov/vehicles/electric_emissions.html
7. Gather the CO_2 equivalent data for the high-emissions and low-emissions state you chose. Complete the chart below, including your own state.

Analyze

In each of these states, the CO_2e of an all-electric vehicle is what percent of the CO_2e of an all-gas vehicle?

State	A: CO_2e all-electric vehicle (lbs/yr)	B: CO_2e all-gas vehicle (lbs/yr)	A is what % of B?

Conclude

Do you think there is any place in the US where an all-electric vehicle produces as much or more CO_2 than does an all-gas vehicle? How much variation is there across the US?

1 One carbon dioxide equivalent, or CO2e, is the amount of heat an equal amount of CO_2 would be expected to trap over the next 100 years.

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"The main benefit of electric cars is that they don't produce the emissions that come from the combustion of gasoline that contribute to climate change. [The] other is particulate emissions: small particles that are leftover when we burn gasoline that can be very harmful to human health and contributes to the smog that we see in some big cities."

Prof. David Keith, MIT Sloan School of Management

TILclimate podcast: Today I Learned About Electric Cars

Air Pollutants

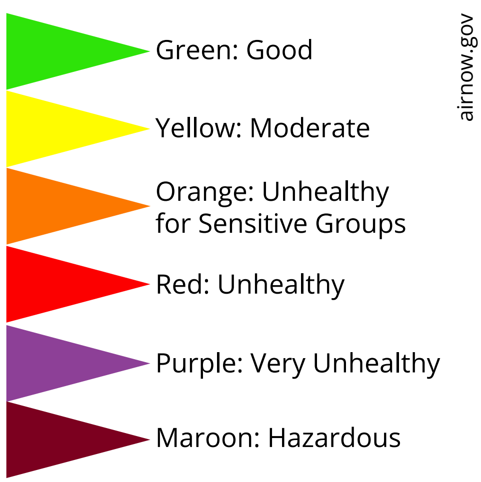
When we burn fossil fuels such as coal, oil, natural gas, and gasoline, particulate matter (PM) and gases such as carbon dioxide (CO_2), nitrogen dioxide (NO_2), sulfur dioxide (SO_2) and ozone (O_3) are released. Most vehicles on the road today burn gasoline or diesel, both of which release these pollutants. Health effects from breathing polluted air include increased asthma, emphysema, heart disease, high blood pressure, and more.[1]

As more people shift to electric vehicles, we will see reductions in air pollution that will dramatically help human health. Columbia University estimates that replacing a single diesel-powered bus with an electric bus could save $150,000 in public health costs.[2]

Improve Air Quality at School

School officials and communities can help protect students, teachers, and staff from harmful air quality in many ways, including ventilation and filtration, site location and design, transportation policies, and roadside barriers. Some of these methods, such as changing building design or buying new buses, may take years. Others may be quicker, such as no-idling rules and maintaining ventilation systems. The needs of each school district and building are different.

Your group will choose one of these action areas and develop a communication plan to encourage changes at your school.



Some communities use the air quality flag system to let people know when the air quality may affect their health.

1 US CDC Air Health https://www.cdc.gov/air/air_health.htm

2 Electric Bus Analysis for New York City Transit, Columbia University, Judah Aber, May 2016 http://www.columbia.edu/

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Best Practices for Schools: Communication Project

Visit https://climate.mit.edu/ed/schoolpollution1[1] and read the three-page document.

Consider Your School

Which of the recommendations are part of a school's overall design?

Which are activities or changes that can be done with an existing school building?

Which are changes in behavior? Who would need to change behavior?

Choose Specific, Achievable Goals

If your town/city is not building a new school building anytime soon, goals around overall building or campus design may not be achievable.

Broad goals, such as "make air quality better at morning drop-off," are hard to achieve. Specific goals, such as "reduce idling vehicles at morning drop-off," are easier to measure.

Research the Issue

If money will need to be spent to achieve your goal, research how projects are funded at your school and in your city/town.

To learn more about the heating, ventilation, and air conditioning (HVAC) system in your school, contact a facilities manager or custodian.

Your school may be eligible for state or federal programs to help pay for changes.

Identify Your Audience

For projects that might cost money, your audience may be the school board, district administration, or a community leader or agency.

If your chosen goal is around behavior (such as open windows, blocked air vents, or idling vehicles), your audience may be your fellow students, school staff, and parents/guardians.

What Is the Best Platform?

How can you best reach your audience? Will they respond best to a meeting, a letter, a poster, a speech at a public event, or a social media campaign?

1 Best Practices for Reducing Near-Road Pollution Exposure at Schools (EPA-420-R-21-022)
https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1013CBT.pdf

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"What we've observed is that we don't buy a vehicle that meets the average needs we have on a day-to-day basis. We buy a car that can serve our 99th percentile needs, which is the long driving holiday that we're going to take or towing the boat or whatever it is."
Prof. David Keith, MIT Sloan School of Management
TILclimate podcast: Today I Learned About Electric Cars

What Is Average Use?

Do you know someone who drives to work, or who uses their car or truck to get around as part of their work? Each person in your class is going to collect data on 1-2 car users they know. You will pool this information to discuss just how much range people need in a car in their day-to-day life.

Interview someone who commutes to work by driving, or who drives their own car or truck for work throughout their workday. (If you know more than one person, especially people with different experiences, interview them if you have time.) If they aren't sure of exact distances, use an online mapping tool (GoogleMaps or similar) to estimate distance.

1. How far (in miles) do they drive each workday?
2. Over the course of a year, how often do they do a longer drive? How far do they drive for those trips?

Make a chart to collect the data from everyone's interviews.

Discussion

Electric charging stations -- while growing in number every year -- are not nearly as common as gas stations. Because of this, drivers are often worried about switching to an electric vehicle (EV). In 2021, EVs averaged a range of 194 miles on a charge, with the shortest range at 84 miles and the longest 396 miles.[1]

Given this range, and the range of vehicle needs your class discovered in your interviews, discuss:

- Could most of the people you interviewed do their daily driving on an average EV charge?
- How often do people drive farther than 194 miles in a single day?
- What are other ways people could meet their infrequent needs for long-distance drives? What are the benefits/drawbacks of these alternatives?

EV charging stations are often somewhat more hidden than a large gas station and may just be a few special parking spots in a parking lot. Visit https://chargehub.com/ to see how many charging spots are in your area.

1 EVBox, How far can an electric car go on one charge? October 2021 https://blog.evbox.com/far-electric-car-range

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"It really feels like we're reaching a place in the market where the technology is maturing and we're seeing many more affordable and long range EVs."
Prof. David Keith, MIT Sloan School of Management
TILclimate podcast: Today I Learned About Electric Cars

How Much Does an EV Cost?

You or someone you know may be excited about the idea of buying an electric vehicle (EV) sometime soon. But just how much does it cost? And how do you factor in the cost of owning it for years to come? Scientists at the MIT Trancik Lab are helping with exactly these decisions.

1. Visit https://www.carboncounter.com/

Observe

How do the different categories of vehicles compare in terms of cost per month?

How do the different categories of vehicles compare in terms of emissions?

2. At the top of the page, click **Customize** and scroll down to the "Quick-select a state filter" and choose your state. (Optional: Change Usage Conditions and prices, if you know them. Otherwise, leave as default.)
3. Hover over the dots in the scatterplot to see the makes and models of vehicles. Choose 1-2 vehicles per category (all-gas, hybrid, all-electric) by clicking on them. (The dots will change to red circles with numbers on them.)
4. Click **Barchart** at the top of the page.

Observe

What do you notice about the costs to run the vehicles you chose? Would you say the costs are about the same, or are one or two much higher than the other(s)?

What do you notice about the emissions for the vehicles you chose? Would you say they are about the same, or are one or two much higher than the other(s)?

Discuss

If you knew someone who was going to get a new car soon, would you recommend that they consider an electric vehicle? Why or why not? What information should they gather before making that decision?

ENVIRONMENTAL SOLUTIONS INITIATIVE