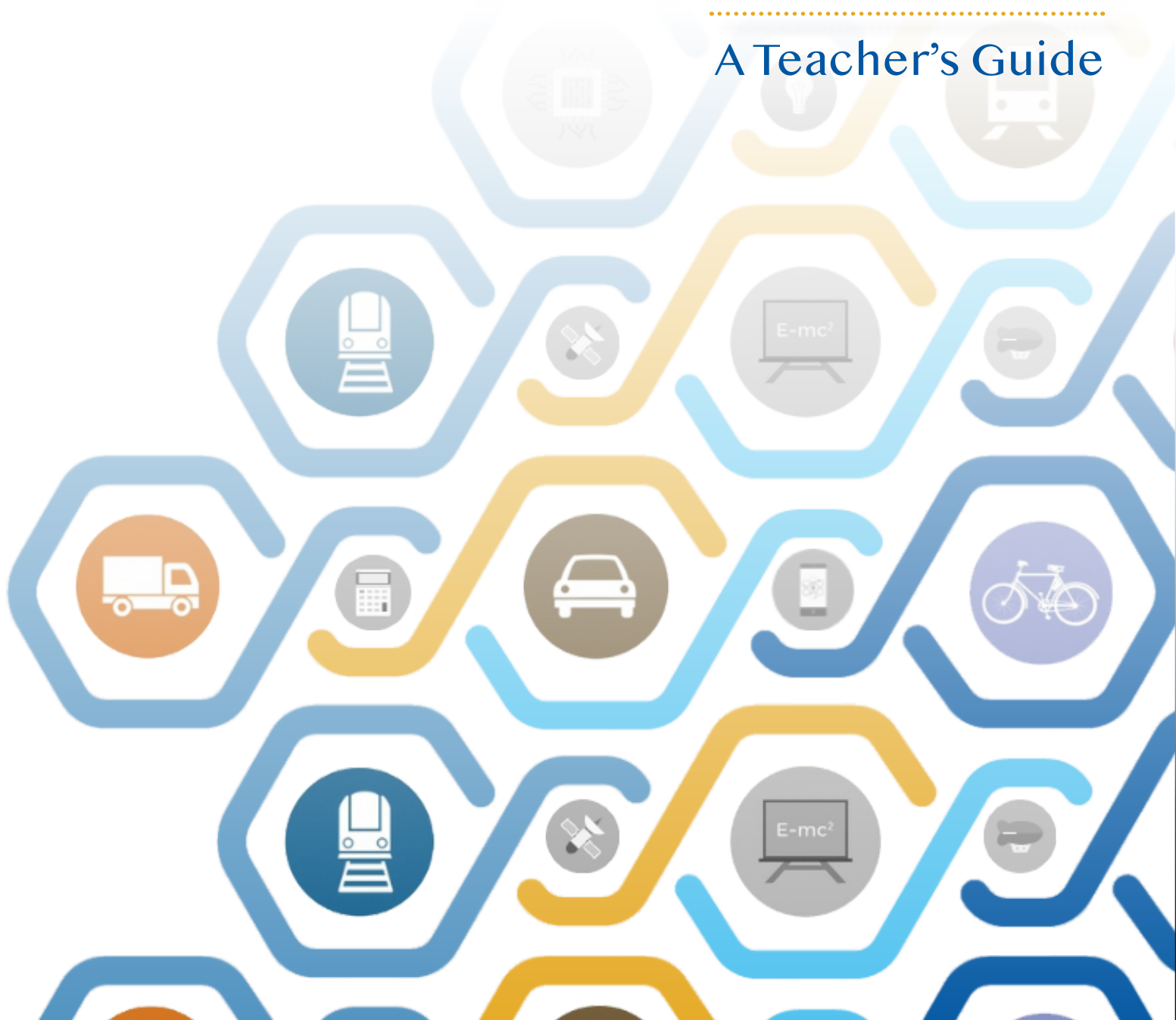


The Garrett Morgan Sustainable Transportation Competition: Transportation for the Future

A Teacher's Guide



The average American spends over 97 hours stuck in traffic each year.

Transportation is the 2nd largest expense for U.S. households.

55 million tons of freight move across the U.S. every day.

Connected vehicles with crash avoidance technology could address 80% of crashes involving unimpaired drivers.

The transportation sector is the biggest source of greenhouse gasses (GHGs) in the U.S.

In 2021, U.S. transportation infrastructure received a C- grade rating, the first time the nation's infrastructure has scored outside the D range in 20 years.

By 2045, the number of Americans over age 65 will increase by 77%.

What does this mean for transportation?

There are expected to be more than 240,000 openings, on average, each year from 2020 to 2030 for urban transportation jobs.

Women accounted for less than 25% of the total transportation and utilities workforce in 2019.

The Mineta Transportation Institute of San Jose State University named the prestigious Sustainable Transportation Award, in honor of Garrett Morgan. This competition is designed to increase middle school students' awareness of transportation issues.

Who was Garrett Morgan?

Garrett Augustus Morgan, an African-American inventor, was born in Kentucky in 1877 to former slaves Sydney Morgan and Elizabeth Reed Morgan. The seventh of ten children, he spent long days working on the family farm. He also attended school but had to quit at age 14 to earn a living. That did not discourage him – he moved to Cincinnati, Ohio, found work as a handyman, hired a tutor, and continued learning. Mr. Morgan eventually moved to Cleveland and became prosperous as a sewing machine repairman who owned his own clothing manufacturing business employing more than 30 people. Later, he established the Cleveland Call, a successful newspaper.



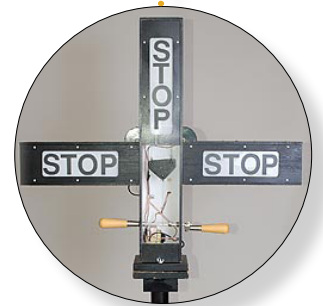
The Gas Mask-- Saving Lives Since 1914

Mr. Morgan had an excellent imagination and invented things we still use today, including a zig-zag stitching attachment for sewing machines. He also invented an early version of the gas mask. When an explosion occurred in a tunnel under Lake Erie, Mr. Morgan volunteered to rescue the trapped workers using his new invention to protect against the deadly fumes. It became an instant success, and he was given the Medal of Bravery by the citizens of Cleveland. He was nominated for the Carnegie Medal but was rejected partly because he was black. Many fire departments wanted his gas mask, too, but they canceled their orders when they learned that a black man had invented it. So, Garrett Morgan hired a white man to pretend he was the inventor, and the gas masks began to sell quickly.



Inventions That Stopped Traffic

As an early owner of an automobile, Mr. Morgan thought that roads could be safer if they had better signaling devices at intersections. At that time, roadways were used for every mode of transportation – autos, wagons, streetcars, horses, bikes, and pedestrians. The existing signals said only “stop” and “go,” which meant that pedestrians were left to compete with all the other traffic. So Garrett Morgan invented a hand-cranked signal that would control traffic at an intersection, and then it would stop all traffic to allow pedestrians to cross. Just before his death in 1963, the U.S. government gave him an award for his invention.



ACKNOWLEDGEMENTS

THANK YOU TO OUR SPONSORS!

American Association of State Highway and Transportation Officials (AASHTO), American Public Transportation Association (APTA), California Department of Transportation (Caltrans), Santa Clara Valley Transportation Authority (VTA), and the United States Department of Transportation (USDOT).

DISCLAIMER

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LETTER TO EDUCATORS

Dear Educator,

Thank you for participating in the Garrett Morgan Sustainable Transportation Competition. The Mineta Transportation Institute realizes that this is an additional activity in your already full curriculum, so we appreciate your efforts.

This learning module is an overview of sustainable transportation issues. You are welcome to cover as many of the lessons that your curriculum will support. Each lesson is all-inclusive, a stand-alone plan, and includes instructor information, as well as student worksheets and other materials relevant to the lesson.

For the competition project, you can have students work in small groups or together as a class. If your class works on more than one project, please select one for presentation. A panel of judges will select the winning project and that school/organization will be invited to send an educator, two student representatives, and a parent or adult guardian on an all-expenses paid trip to San José, California to attend MTI's annual banquet. The winning class will also receive \$1,000 and a plaque, while the second and third place teams will win \$500 and a plaque, and \$200 and a plaque, respectively. Each student who competes will receive a signed certificate of participation.

Please note that you are encouraged to adjust these lessons to fit the specific needs of your students and your classroom. Shifting the approach of the lesson can enable you to use the materials to meet the standards emphasized by the grade level you are teaching. This project is an outstanding way to work across disciplines and collaborate with ELA and Physical Sciences teachers, lifting each other up and empowering all students at the same time.

We hope that you and your class enjoy this unit. Please let us know if you have suggestions or feedback.

Thank you again.



Karen Philbrick, PhD
Executive Director
Mineta Transportation Institute



Hilary Nixon, PhD
Deputy Executive Director
Mineta Transportation Institute

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THE COMPETITION

It is not necessary to create a project based exclusively on the material in this workbook. These exercises simply provide insight into transportation, energy sources, environmental effects, career choices, etc. Your project should incorporate any aspect of sustainable transportation, and you are encouraged to be as creative as you like – just make sure you can defend the feasibility of your project.

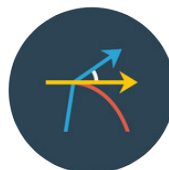
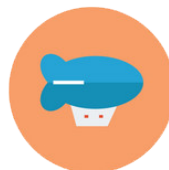
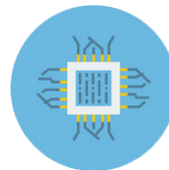
THE TEAM

Each school/organization will identify one team of students to present their project to a panel of judges. These teams may be as large as needed to develop the project, but for presentation purposes should be narrowed down to five (5) student representatives. There must be at least three (3) students participating in order for a team to compete.

THE PROJECT

Your project could be based on a vehicle and/or a system of transportation or an idea for solving part(s) of the sustainable transportation problem. Below are some suggestions:

- **Project.** Develop your own transportation system or mode. This can be a new car, a better bus, or a transportation plan for an entire city or one just for friends. In the past, many teams have created vehicles that use solar or wind power. We encourage you to be creative and come up with something new. Imagination counts!
- **Legislation.** If you were mayor, governor, or president, what laws do you think would help make better transportation systems? Develop some local, state, or federal legislation that will promote sustainable transportation and explain why it will be beneficial. What problems still remain to be solved?
- **Research Study.** Document current sustainable transportation practices in your community. The project can include any transportation mode, method, or anything that encourages sustainable transportation where you live. Are those practices successful? How can they be improved? What problems are still not being addressed? What particular groups of people are not being served? How would you better serve them?



THE PRESENTATION

Teams must prepare and submit one final presentation video no more than 7-10 minutes. The panel of judges will review the videos. In addition, the MTI Executive Director (who is not a judge) will travel to schools in the Bay Area and Washington, DC to watch the presentations in person.

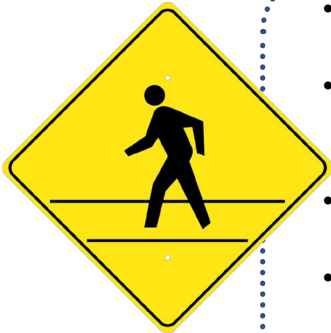
Presenting team shall consist of a maximum of 5 student representatives. Often teams use PowerPoint slides as part of their presentation (use powerful slides that aren't too wordy and avoid using too many slides), but you can also create a model or other display. If you use a model or other display, make sure that the materials can be clearly visible on a video screen.

JUDGING CRITERIA

The competition will have three impartial judges who have no personal interest in the outcome. They will award a maximum of 130 points based on several criteria, including:

- Does the project clearly solve part of the sustainable transportation problem?
- Is the presentation clear / do the students speak clearly and knowledgeably?
- Does the visual presentation support the team's overall project?
- Does the team work well together, and are they prepared?

The scoring rubric is available for download from MTI's [website](#). Here are some hints as you prepare for your presentation:



- Judges like presentations that are enthusiastic and clear.
- Practice several times! Judges can tell when you haven't practiced.
- Practice challenging your idea so you can learn how to defend it.
- Speak clearly and slowly. The judges want to hear you.
- Have fun! Everyone is really interested in your project.

Americans spend over 40 hours stuck in traffic each year.

Lesson 1: What Do You Know About Transportation?

DESCRIPTION

This lesson will help the students become aware of various forms of transportation. Students will focus on why transportation is needed, the different modes of transportation, and various energy sources used by different transportation modes.

LEARNING OUTCOMES

At the completion of this lesson, students will be able to:

- List different forms of transportation
- Explain how we use different modes of transportation
- Identify different energy sources used by transportation
- Describe some of the environmental impacts of transportation



LESSON TIME

- One class period

STANDARDS AND OBJECTIVES

Next Generation Science Standards

- **MS-ESS3-1 Earth and Human Activity.** Connections to Engineering, Technology, and Applications of Science Influence of Science, Engineering, and Technology on Society and the Natural World
 - All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment

California Common Core Standards

- **Writing Standards (Grades 6–12).** Write arguments to support claims with clear reasons and relevant evidence.
- **Speaking and Listening Standards (Grades 6–12).** Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on texts, and issues, building on others' ideas and expressing their own clearly.

MATERIALS

- “What Do You Know About Transportation” student worksheet (one copy per student, or one copy per group depending on how you structure the activity)

INSTRUCTIONAL ACTIVITY

With guidance from the teacher, students will brainstorm and fill in the “What Do You Know About Transportation” worksheet for each of the following areas related to transportation:

1. How do we use transportation? Why do people need transportation?
2. What are the different modes/types of transportation?
3. What are the different energy sources used by transportation?
4. What are some of the environmental impacts of transportation?
5. Which form of transportation is the oldest? Which ones are newest? How do you know?

The brainstorm session can take place in small groups, or in a larger classroom discussion. It may be best to focus on one question at a time. The teacher may guide students to think about transportation issues that they might not have considered. For example, how does the US Postal Service use transportation, and how do shipping companies, grocery stores, or the military use transportation. Have students considered different modes of public transportation? What about non-vehicular modes of transportation?

After the four lists are compiled, have students link the different reasons for using transportation with the various modes and energy sources of transportation. Teachers can help illustrate these relationships by drawing lines connecting the various related reasons, modes, and energy sources.

A completed example table is provided for teachers. As part of the class discussion, the instructor may ask students how these different aspects of transportation are related – for example, what modes of transportation do students use to get to/from school? What energy sources do different modes of transportation use?

ADDITIONAL ACTIVITY SUGGESTIONS

With guidance from the teacher, students will brainstorm and fill in the “What Do You Know About Transportation” worksheet for each of the following areas related to transportation:

1. Students draw and/or cut out images of the forms of transportation and create a collage or other visual representation (e.g., illustration of one form per small group).
2. Students hypothesize about future forms of transportation and draw and/or write a description of their idea.

Example Completed Table for Teacher

1. Uses	2. Modes	3. Energy Sources	4. Effects
Get to school	Car	Gasoline	Greenhouse gas emissions
Get to work	Light rail transit	Diesel	Climate change
Vacations	Train	Jet fuel	Smog
Shopping	Ship	Solar energy	Air pollution
Visiting	Airplane	Electricity	Fuel spills
Emergencies	Truck	Natural gas	Noise pollution
	Boat	Ethanol	Congestion
	Bicycle	Calories	Sidewalk clutter
	E-bike/E-scooter (etc.)	Hybrids	
	Walking	Fuel cell	

Transportation is the 2nd largest expense for U.S. households.

Lesson 2: Key Innovations in Transportation

DESCRIPTION

This lesson will help develop students' awareness of the social, environmental, and economic costs of our transportation systems' dependence on fossil fuels through a historical perspective.

LEARNING OUTCOMES

Students will be able to:

- Identify key events in U.S. transportation history
- Understand the impact specific transportation-related events have had
- Discuss the economic, social, and environmental costs and/or benefits of specific transportation-related events



LESSON TIME

- One class session (helpful to have students read through the timeline in advance so that they are familiar with the events)

STANDARDS AND OBJECTIVES

Next Generation Science Standards

- **MS-ESS3-1 Earth and Human Activity.** Connections to Engineering, Technology, and Applications of Science Influence of Science, Engineering, and Technology on Society and the Natural World
 - All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment

California Common Core Standards

- **Writing Standards (Grades 6–12).** Write arguments to support claims with clear reasons and relevant evidence.
- **Speaking and Listening Standards (Grades 6–12).** Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on texts, and issues, building on others' ideas and expressing their own clearly.
- **Reading Standards for Informational Text (Grades 6–12)**
 - Cite specific textual evidence to support analysis of science and technical texts.
 - Integrate quantitative or technical information expressed in words in a text with

a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table)

MATERIALS

This lesson includes visual representations of key transportation innovations throughout history. Use the links below to access the student and teacher slide decks or use the handout as an alternative.

- [Student Slides](https://tinyurl.com/GM-InnovationTimeline-Student) (<https://tinyurl.com/GM-InnovationTimeline-Student>)
- [Teacher's Answer Key](https://tinyurl.com/GM-InnovationTimeline-Answer) (<https://tinyurl.com/GM-InnovationTimeline-Answer>)
- "Transportation History: Timeline of Events" student handout

INSTRUCTIONAL ACTIVITY

Student slides are shuffled (not in chronological order). Students can work in pairs or small groups to try to move the slides into the correct chronological order. If time permits, students can share their timeline (order of their slides) out loud and/or move about the room to compare their timeline with that of other groups.

Students should consider, discuss, and share their rationale for their timeline as well. Which innovation came first? How do you know/why do you think that? What clues helped you come to this conclusion?

When students are ready to discuss their timeline, have students read the "Transportation History: Timeline of Events" handout and show the Answer Key slides. In groups, students should discuss the economic, social, and environmental costs and/or benefits of the event. Each student will complete the directions on the timeline for further discussion on the impacts of these innovations.

Alternatively, the instructor can go through each event together with the class. Students can take turns reading events out loud. The discussion for each event should focus on the economic, social, and environmental costs and/or benefits of the event. A list of guiding questions/additional comments for each event for the instructor is provided below.

54 million tons of freight move across the U.S. every day.

KEY INNOVATIONS IN TRANSPORTATION TIMELINE

STUDENT HANDOUT

DATE

August 1803



EVENT

Robert Fulton creates a steamboat that operates up the River Seine in Paris, moving 3-4 miles per hour upstream.

May 1869



Passenger traffic begins on the first pneumatic subway invented by Alfred Ely Beach. The Beach Pneumatic Underground Railway of New York City includes a 312 foot-long circular tube, 9 feet in diameter. The cars carry 22 passengers and are propelled by a blast of air from a rotary blower.

January 1900



The first electric bus appears on 5th Avenue in New York City. It seats eight people inside and four outside. The fare is 5¢.

October 1904

The New York City Subway is the first rapid transit underground and underwater railway in the world. It runs from City Hall to West 145th St.

April 1913

The first electrically propelled ship of the U.S. Navy, the USS Jupiter, is commissioned.

November 1923



Garrett Morgan is granted a patent for inventing the first practical traffic signal.

March 1927

The first automobile to exceed 200 miles per hour is the "Mystery Sunbeam" driven by Major Henry O'Neil de Hane Segrave at Daytona Beach, FL. He hits 203.79 mph.

September 1931

An experimental electric passenger train, designed by Thomas Alva Edison, is used on the Lackawanna Railroad between Hoboken and Montclair, NJ.

July 1935

The first parking meter, called The Black Maria, is installed in Oklahoma City, OK.

June 1956



President Dwight Eisenhower signs a bill that creates the first interstate highway in the U.S. The system is not completed until 1990.

August 1959

An early modern type of magnetic levitation (maglev) train is described in a US Patent by G.R. Polgreen.

April 1961



The first human spaceflight is Vostok I, on which cosmonaut Yuri Gagarin of the USSR makes one orbit around Earth.

DATE

October 1964

**EVENT**

Japan's Shinkansen, the first "bullet train," opens.

January 1969

An oil well blows out on a Union Oil Company drilling platform five miles off the coast of Santa Barbara, CA. The beaches are covered with oil. In April 2010, the same thing happens in the Gulf of Mexico, where BP was drilling.

July 1979

President Carter announces a massive six-point effort to reduce American dependence on foreign oil, including alternative energy development.

March 1989



Exxon Valdez oil tanker runs aground in Alaska, spilling 232,000 barrels of oil. Only 25% of the migratory salmon population returns the following season. Thousands of otters and birds are poisoned. Many die.

July 2006



The Tesla Roadster is introduced at the Santa Monica, CA airport at a 350-person invitation-only event. The Roadster costs more than \$100,000.

August 2008



SmartBike DC in Washington, D.C. launches the first docked bike sharing system.

March 2009



Uber, a ride-hailing company, launches in San Francisco, CA.

April 2009

President Obama unveiled his administration's blueprint for a national network of high-speed passenger trains.

December 2009



China introduced the world's fastest train, with average speeds of 217 miles per hour.

July 2012

California legislature under Gov. Jerry Brown approves the construction of a high-speed system.

DATE

May 2013

October 2014



January 2015



September 2016

December 2016

April 2017



April 2017

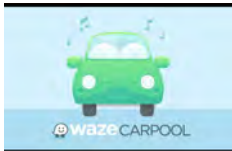
June 2017

September 2017



January 2018

October 2018



July 2019

EVENT

The New York Times runs a story about young people leading a trend toward driving less and taking transit instead.

Tesla releases the Model S, the first electric, semi-autonomous vehicle for general use.

California High Speed Rail breaks ground in Fresno.

The U.S. Department of Transportation announces new regulations for automated vehicles and self-driving cars to ensure that they are safe.

Tesla CEO Elon Musk founds The Boring Company with the goal of creating a subterranean tunnel system for passenger vehicles. The company is also working on hyperloop technology.

California Senate Bill 1 passes. This "gas-tax" collects funds to repair roads, improve traffic safety, and expand public transit systems in California.

The highly controversial Dakota Access Pipeline has a 168 gallon crude oil leak. The pipeline had several other leaks throughout 2017-2019.

The United States under the Trump administration withdraws from the Paris Agreement on climate change mitigation. Several other climate change policies were revoked earlier that year.

Dockless e-scooters launch in Santa Monica, CA with mixed reviews due to lack of laws and regulations on micromobility.

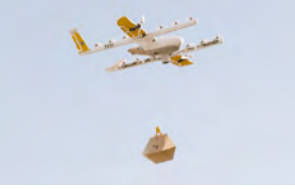
Brightline high-speed train in Florida opens for public operation between West Palm beach and Fort Lauderdale.

Waze launches carpool matching feature nationwide. The company predicts it will reach 1M carpool rides by 2020.

Uber reveals its helicopter ride-share service, Uber Copter.

DATE

October 2019

**EVENT**

Wing launches first commercial drone delivery.

October 2021



The world's first urban autonomous water vessels, Roboats, are deployed in the canals of Amsterdam. The vessels can be used to carry up to five people, collect waste, or deliver goods.

January 2022



A driverless bullet train that can transport 564 passengers at 217 mph is revealed in China in time for the Winter Olympics.

February 2022

Autonomous Vehicle company Cruise launches a robotaxi line in San Francisco, CA that is open to the public.

August 2022

The first rail line running entirely on hydrogen power debuts in Germany. The trains are expected to keep 4,000 tons of carbon dioxide out of the atmosphere each year.

1. Identify three items from the timeline that you could see being adapted today to create a more sustainable mode of transportation. Jot down how beside the event.
2. Circle those items on the timeline that MOST negatively impact the environment.
3. Place a dollar sign symbol [\$] beside those events on the timeline that generate money for city improvements or maintenance.
4. Discuss and compare your results.

Lesson 3: Learning About Transportation Fuels¹

DESCRIPTION

This lesson will help students learn more about transportation fuels, including alternative fuels through a close reading exercises. Students will develop an understanding of some of the current issues related to petroleum as a source of fuel as well as identify what other sources of fuel can be used by transportation. The focus is on motor vehicle transportation.

LEARNING OUTCOMES

Students will be able to:

- List the main features of different transportation fuels
- Compare and contrast the advantages and disadvantages of different transportation fuels



LESSON TIME

- Several class periods, depending on how the activity is structured

STANDARDS AND OBJECTIVES

Next Generation Science Standards

- **MS-ESS3-1 Earth and Human Activity.** Connections to Engineering, Technology, and Applications of Science Influence of Science, Engineering, and Technology on Society and the Natural World
 - All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment
- **MS-ESS2-1. Earth's Systems.** Develop a model to describe the cycling of Earth's materials and the flow of energy that drives this process.
- **MS-PS3-1 Energy**
 - **PS3.A: Definitions of Energy.** Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object.
 - Analyzing and Interpreting Data - Construct and interpret graphical displays of data to identify linear and nonlinear relationships.

1. This lesson is drawn from materials prepared by the National Energy Education Development Project. The original set of materials, including additional activities, can be found at <http://www.need.org/files/curriculum/guides/ElementaryTransportationFuelsInfobook.pdf> and <http://www.formula-hybrid.org/wp-content/uploads/DOE-Alternative-Fuels-Teacher-Guide.pdf>.

- **MS-PS3-5. Definitions of Energy.** Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.
 - Energy and Matter - Energy may take different forms (e.g. energy in fields, thermal energy, energy of motion).
- **MS-LS1-6 From Molecules to Organisms: Structures and Processes.** Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms.
 - **LS1.C:** Organization for Matter and Energy Flow in Organisms
 - **PS3.D:** Energy in Chemical Processes and Everyday Life
- **MS-LS2-1 Ecosystems: Interactions, Energy, and Dynamics.** Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.
 - **MS-LS2-3 Ecosystems: Interactions, Energy, and Dynamics.** Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem
 - **MS-LS2-4 Ecosystems: Interactions, Energy, and Dynamics.** Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations

California Common Core Standards

- **Reading Standards for Informational Text (Grades 6–12)**
 - Cite the textual evidence that most strongly supports an analysis of what the text says explicitly as well as inferences drawn from the text.
 - Determine a central idea of a text and analyze its development over the course of the text, including its relationship to supporting ideas; provide an objective summary of the text.
- **Writing Standards (Grades 6–12)**
 - Write arguments to support claims with clear reasons and relevant evidence.
 - Write informative/explanatory texts to examine a topic and convey ideas, concepts, and information through the selection, organization, and analysis of relevant content.
 - Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.
 - Draw evidence from literary or informational texts to support analysis, reflection, and research.
 - Use technology, including the Internet, to produce and publish writing and link to and cite sources as well as to interact and collaborate with others, including linking to and citing sources.
 - Conduct short research projects to answer a question, drawing on several sources and generating additional related, focused questions for further research and investigation.

- Gather relevant information from multiple print and digital sources, using search terms effectively; assess the credibility and accuracy of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation.
- **Reading Standards for Informational Text (Grades 6–12)**
 - Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners texts, and issues, building on others' ideas and expressing their own clearly
 - Analyze the main ideas and supporting details presented in diverse media and formats (e.g., visually, quantitatively, orally) and explain how the ideas clarify a topic, text, or issue under study
 - Present claims and findings (e.g., argument, narrative, summary presentations), emphasizing salient points in a focused, coherent manner with pertinent descriptions, facts, details, and examples; use appropriate eye contact, adequate volume, and clear pronunciation.

MATERIALS

- Alternative Fuels Information Student Worksheet – Background (all students receive a copy of this worksheet)
- Alternative Fuels Information Student Worksheets – Individual Fuels (assign one fuel to each group and provide a copy of the relevant worksheet)
- Student Activity Guidelines

INSTRUCTIONAL ACTIVITY

In groups, students will conduct research on a specific fuel. All students should receive a copy of the “Alternative Fuels Information Student Worksheet – Background” handout, which provides basic information about some of the issues surrounding petroleum as a source of transportation fuel and introduces the concept of alternative fuels. Then, each group should be assigned to learn about one of the fuel options and present what they learn to their class using the information worksheet for their fuel type: gasoline; diesel; biodiesel; hybrid electric vehicles; electric vehicles; ethanol; propane; natural gas (CNG/LPG); and hydrogen. Encourage students to use close reading skills by highlighting important information, circling unfamiliar words, asking questions, etc.

Depending on your preference, groups could present what they have learned to the class in a variety of ways. Common options include a poster and/or oral presentation, but other options are possible such as a PowerPoint presentation, a written paper, a flyer, infographic, or a short video. The learning activity is intended to be flexible. Students are encouraged to look at additional resources for information as well. Some online references are provided, but you may wish to supplement with other resources as well.

OPTIONAL ADDITIONAL ACTIVITY

As a supplemental activity you may wish to consider the following “mini activity” to help students understand some of the constraints associated with the use of alternative fuels. The U.S. Department of Energy has developed an Alternative Fueling Station Locator (<http://energy.gov/maps/alternative-fueling-station-locator>). At this site, you can find the locations of different types of alternative fuel stations around the U.S. You may want to list your school’s address and select different fuel types to see the availability around you. Another great activity is to “Plan a Route.” Maybe you want to see whether you can travel from your school to, for example, your state capital using a variety of alternative fuels. This activity can be adapted in many different ways.



ALTERNATIVE FUELS INFORMATION STUDENT WORKSHEET - BACKGROUND



For more than a hundred years, petroleum has fueled our vehicles. In the United States, we use approximately 20.5 million barrels of oil each day to keep us on the move.² It's no wonder that petroleum is often called "black gold."

The automobile is important to the way we live. According to the U.S. Department of Transportation, Americans drove approximately 3.23 trillion miles in 2021.³

These vehicles all need fuels that we can afford and that are easy to find. Today, over 80 percent of our vehicles run on gasoline or diesel fuels. America's whole system of refineries, pipelines, and service stations was designed for oil-based fuels. But there are problems with using petroleum fuels.

Today, the United States imports about half of its petroleum from other countries. We need a supply that is reliable. The unrest in the Middle East could cause oil shortages or very high prices at any time. In the summer of 2008, the cost of a barrel of crude oil soared to \$133, an all-time high, and in 2022 gas prices reached as high as \$6.23 per gallon in California, due in part to international factors and high demand for crude oil.

Auto manufacturers have done a good job of reducing emissions from vehicles. Since the 1960s, emissions have dropped by more than 95 percent. Still, the pollutants cause health and environmental problems, and contribute to global climate change.

The vehicles on the road today cause half of the air pollution in many cities. According to the U.S. Environmental Protection Agency, almost half of all Americans live in polluted areas. This has led to an effort to develop alternatives to petroleum fuels.

TAKING AN ALTERNATIVE ROUTE



The United States is big; Americans travel more miles than the citizens of any other country. And we use more petroleum than any other country. In many areas, this is causing air pollution problems.

There is no simple answer that can solve the problem, but using alternative fuels can help. Alternative fuels emit fewer air pollutants. Using alternative fuels can also reduce emission of carbon dioxide, a greenhouse gas. Combustion of any carbon-based fuel produces carbon dioxide, but the overall impact of a fuel depends on how the fuel is made. Fuels produced from biomass and from natural gas result in less carbon dioxide than fuels from petroleum.

With rising gasoline prices and concern for the environment, more and more people are looking at using alternative fuels to fuel their vehicles. Alternative fuels—such as propane, natural gas, ethanol, biodiesel, and electricity—all can help. Each of these alternative fuels has advantages and disadvantages. Every year, people have the choice of more alternative fuel vehicles.

2. Source: U.S. Department of Energy (2019). Frequently Asked Questions. <https://www.eia.gov/tools/faqs/faq.php?id=33&t=6>
3. Source: U.S. Department of Transportation. <https://www.reuters.com/world/us/us-driving-soars-2021-up-112-2021-2022-02-18/>



ALTERNATIVE FUELS INFORMATION STUDENT WORKSHEET - GASOLINE



Gasoline is a fuel made from petroleum. It is used in most U.S. passenger vehicles with internal combustion engines. In 2021, Americans used 19.89 million barrels of petroleum per day. This means about 134.83 billion gallons of finished motor gasoline were consumed in the United States, an average of about 369 million gallons per day.

HISTORY OF GASOLINE



Edwin Drake dug the first oil well in 1859 and distilled the petroleum to produce kerosene for lighting. He had no use for the gasoline or other products, so he discarded them. It wasn't until 1892 with the invention of the automobile that gasoline was recognized as a valuable fuel. By 1920, there were nine million vehicles on the road powered by gasoline and service stations were popping up everywhere.

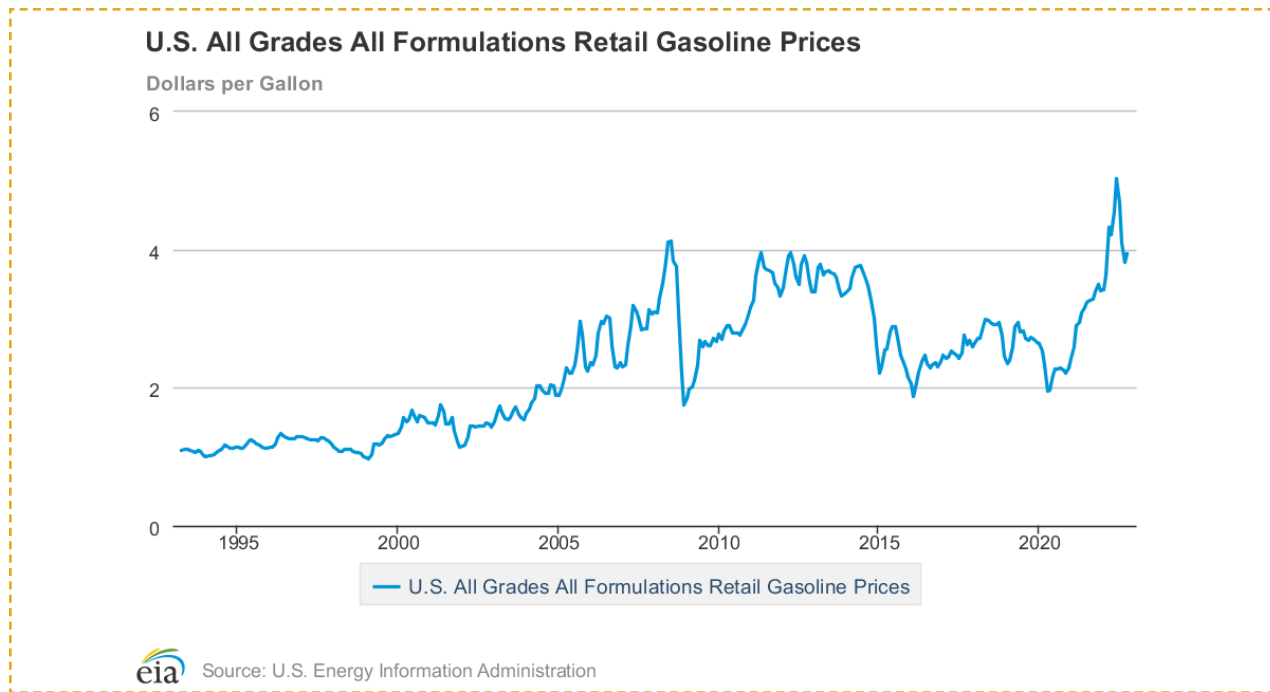
During the 1950s, cars were becoming bigger and faster. Octane ratings increased and so did lead levels, as lead was added to gasoline to improve engine performance. Unleaded gasoline was introduced in the 1970s, when the health problems from lead became clear. Leaded gasoline was completely phased out in the 1980s.

GASOLINE AS A TRANSPORTATION FUEL



Today, gasoline is the fuel used by most of the passenger vehicles in the U.S. There are about 249 million vehicles that use gasoline to travel an average of 13,476 miles per year. There are 145,000 fueling stations that provide convenient refueling for consumers. Most Americans consider gasoline the most sensible fuel for today, even if it is not an ideal fuel.

Consumers worry about the price of gasoline. During World War I, the cost of gasoline was about \$0.25 a gallon. The price of gasoline has averaged about \$2.00 a gallon in inflation-adjusted dollars for the last 80 years, until the shortages after Hurricanes Katrina and Rita and unrest in oil-producing countries such as Iran, Iraq, and Nigeria. In the summer of 2008, the average price for a gallon of gasoline was the highest ever at \$4.39. However, in 2015, the average price for a gallon of gasoline was only \$2.40. Due to higher demand and international factors, gas prices soar in 2022 to a high of \$6.23 in California.



CHARACTERISTICS AND ENVIRONMENTAL IMPACTS OF GASOLINE



Gasoline has high energy content. It is highly flammable and toxic—gasoline vapors can cause dizziness, vomiting, and even death if inhaled in strong concentrations. Gasoline is a nonrenewable fossil fuel that produces air pollutants when it is burned. Since the 1960s, stricter environmental standards have led to gasoline and vehicle designs that have reduced vehicle exhaust emissions by 95 percent.

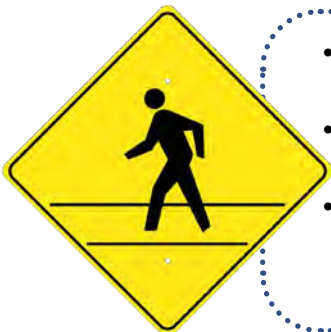
The Clean Air Act Amendments of 1990 required that reformulated gasoline be used in areas of the country that do not meet air quality standards, to reduce emissions and improve air quality. In 2002, more than a dozen different types of gasoline were required by law in the U.S.

Even with reductions in emissions, the impact of gasoline on the environment is immense, because there are so many vehicles in the United States driving so many miles. It will take the dedicated efforts of consumers, the transportation industry, and federal and state governments to make significant changes to our transportation system.

ADDITIONAL RESOURCES



- U.S. Energy Information Administration: www.eia.gov
- Alternative Fuels Data Center: <http://www.afdc.energy.gov/>
- U.S. Environmental Protection Agency: Transportation, Air Pollution, and Climate Change: <https://www.epa.gov/air-pollution-transportation>





ALTERNATIVE FUELS INFORMATION STUDENT WORKSHEET - DIESEL



Diesel is a petroleum fuel that contains energy. At refineries, crude oil is separated into different fuels including gasoline, jet fuel/kerosene, lubricating oil, and diesel. Approximately ten gallons of diesel are produced from each 42-gallon barrel of crude oil. Diesel can only be used in a diesel engine, a type of internal combustion engine used in many cars, boats, trucks, trains, buses, and farm and construction vehicles.

HISTORY OF DIESEL



Rudolf Diesel originally designed the diesel engine to use coal dust as a fuel, but petroleum was more effective. The first diesel-engine automobile trip was completed on January 6, 1930. The trip was from Indianapolis to New York City, a distance of nearly 800 miles. This achievement helped prove the usefulness of the diesel engine design. It has been used in millions of vehicles since then.

DIESEL AS A TRANSPORTATION FUEL



Diesel fuel plays an important role in America's economy, quality of life, and national security. As a transportation fuel, it offers a wide range of performance, efficiency, and safety features. Diesel fuel contains between 18 and 30 percent more energy per gallon than gasoline. Diesel technology also offers a greater power density than other fuels, because it provides more power per volume.

Diesel fuel is used for many things. Diesel powers more than two-thirds of all farm equipment in the U.S. because diesel engines can perform demanding work. In addition, it is the most commonly used fuel for public buses and school buses throughout the U.S.

America's construction industry depends on the power of diesel fuel. Diesel engines are able to do demanding construction work, like lifting steel beams, digging foundations and trenches, drilling wells, paving roads, and moving soil—safely and efficiently. Diesel also powers the movement of America's freight in trucks, trains, boats, and barges; 94 percent of our goods are shipped using diesel-powered vehicles. No other fuel can match diesel in its ability to move freight economically.

Several auto manufacturers are in the process of releasing new models of light-duty diesels and passenger cars. Within the next few years, demand for diesel vehicles is expected to increase greatly in the U.S.

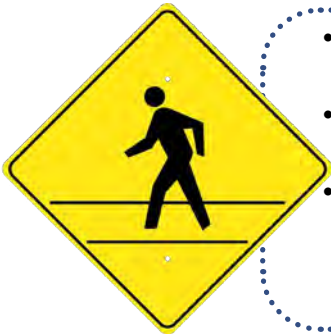
CHARACTERISTICS AND ENVIRONMENTAL IMPACTS OF DIESEL



Diesel-powered cars achieve 30-35 percent better fuel economy than gasoline powered cars, especially in sport utility vehicles (SUVs) and light trucks, which now make up more than half of all new vehicle sales. Safety is another advantage of diesel fuel; it is safer than gasoline and other alternatives because it is less flammable.

The major disadvantage of diesel fuel is its harmful emissions. Pollutants associated with the burning of diesel fuel are gaseous emissions, including sulfur dioxide (SO₂) and nitrogen oxide (NO_x), and particulate matter. Major progress has been made in reducing emissions from diesel engines. New diesel fuels—some of which have lower sulfur content—can also help diesel vehicles achieve lower emissions. As of 2010, new trucks and buses have near zero emission levels. Ultra low sulfur diesel (ULSD) fuel is highly refined for clean, complete combustion and low emissions. Using low sulfur diesel fuel and exhaust control systems can reduce particulate emissions by up to 90 percent and nitrogen compounds (NO_x) by 25-50 percent. In 2021, distillate fuel consumption by the U.S. transportation sector, which is essentially diesel fuel, was about 46.82 billion gallons (1.11 billion barrels), an average of about 128 million gallons per day. This amount accounted for about 77% of total U.S. distillate consumption, about 15% of total U.S. petroleum consumption, and on an energy content basis, about 25% of total energy consumption by the U.S. transportation sector.

ADDITIONAL RESOURCES



- U.S. Energy Information Administration: www.eia.gov
- Alternative Fuels Data Center: <http://www.afdc.energy.gov/>
- U.S. Environmental Protection Agency: Transportation, Air Pollution, and Climate Change: <https://www.epa.gov/air-pollution-transportation>



ALTERNATIVE FUELS INFORMATION STUDENT WORKSHEET - BIODIESEL: FUEL FROM FRENCH FRIES?



Biodiesel is a fuel made from vegetable oils or animal fats. It is usually made from soybean oil, but it can also be made from corn oil or even used restaurant grease and fryer oil. If it is made from restaurant oil, it can sometimes smell like french fries. Since biodiesel is made from plant and animal oils, it is a renewable fuel. We can grow more plants in a short time to make more biodiesel.

BIODIESEL AS A TRANSPORTATION FUEL



Biodiesel works as well in engines as diesel fuel. In many ways, it is a better fuel, though it is more expensive. Burning biodiesel does not produce as much air pollution as burning petroleum fuels. This means the air is cleaner and healthier to breathe when biodiesel is used. Biodiesel is also nontoxic—it is not dangerous to people or the environment, and is safe to handle. If biodiesel spills, it is biodegradable—it breaks down quickly into harmless substances.

Biodiesel can be used instead of diesel fuel, or it can be mixed with diesel fuel. It is usually mixed with diesel fuel as a two percent (B2), five percent (B5), or 20 percent (B20) biodiesel blend. Pure biodiesel is called B100. That means it is 100 percent biodiesel. The B stands for biodiesel, and the number stands for the percent of biodiesel in the mixture or blend.

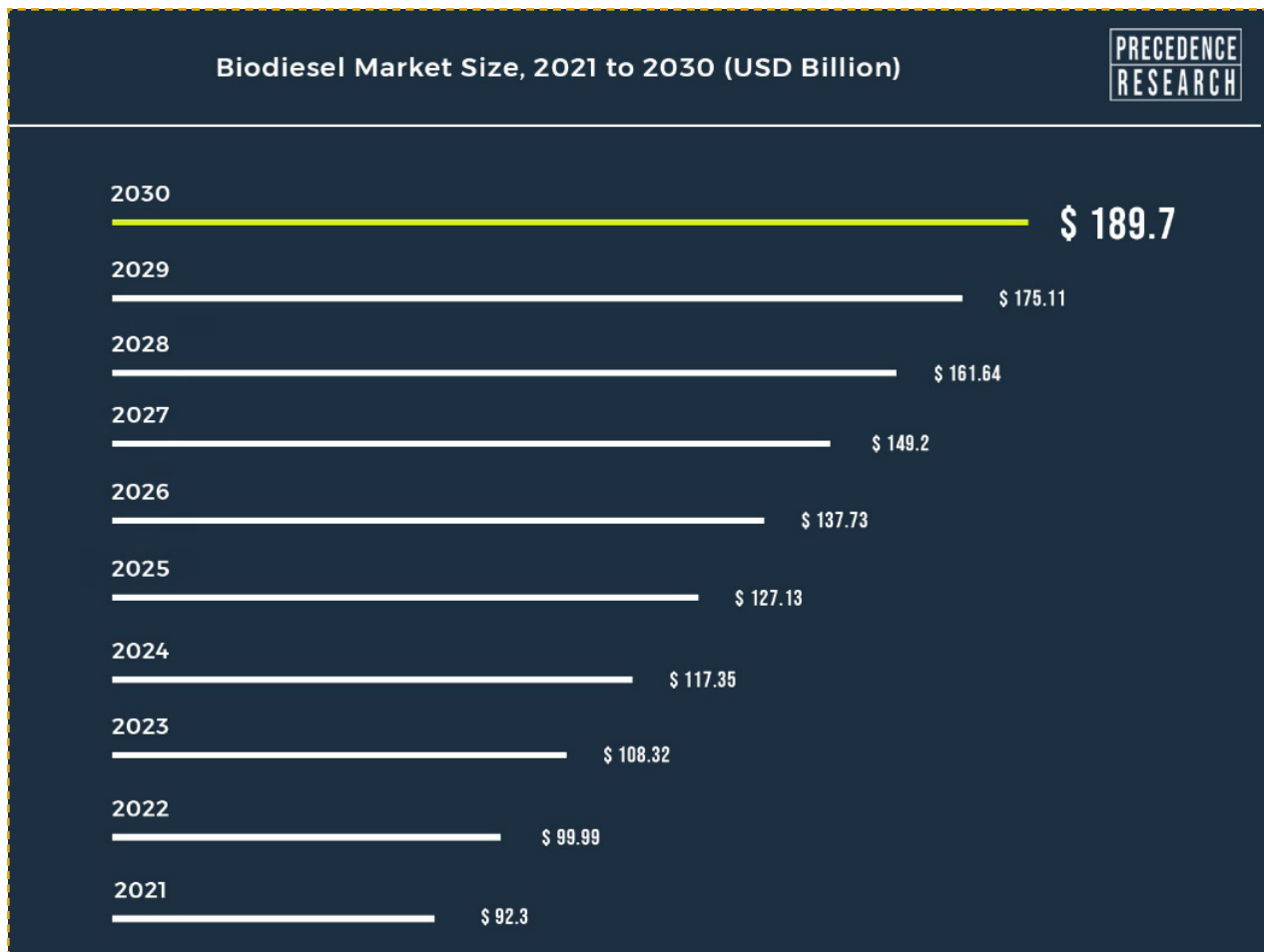
Most biodiesel used today is B20, which is 20 percent biodiesel and 80 percent diesel. Many school districts have begun using B20 in their school buses. In Arizona's Deer Valley Unified School District, school buses have been running on B20 since 1999. These buses drove over 2.5 million miles per year on B20. Everyone involved is pleased with the way the buses operate and believe using biodiesel improves the environment and the health of the students and drivers.

Many cities, as well as the U.S. Army, Air Force, and Department of Agriculture, are using biodiesel to run their buses, garbage trucks, snowplows, and other vehicles. These fleets have their own fueling stations. Biodiesel fuels are also becoming more available at public stations, as consumer demand grows.

ENVIRONMENTAL IMPACTS



Biodiesel is a renewable fuel. It is environmentally safe, biodegradable, and reduces the emission of most air pollutants.



BIODIESEL TODAY AND TOMORROW



Today, biodiesel is mainly available through bulk suppliers. According to the U.S. Department of Energy, there are 822 biodiesel refueling stations with public access in the United States as of 2022. That means biodiesel is more practical for fleets with their own fueling stations. More stations will open as the demand for biodiesel grows.

Today, B20 costs a little more than diesel fuel. The cost will go down as more biodiesel is used. Many states are planning to require that all diesel fuels have a small amount of biodiesel to reduce sulfur emissions.

ADDITIONAL RESOURCES



- U.S. Energy Information Administration: www.eia.gov
- Alternative Fuels Data Center: <http://www.afdc.energy.gov/>
- U.S. Environmental Protection Agency: Transportation, Air Pollution, and Climate Change: <https://www.epa.gov/air-pollution-transportation>





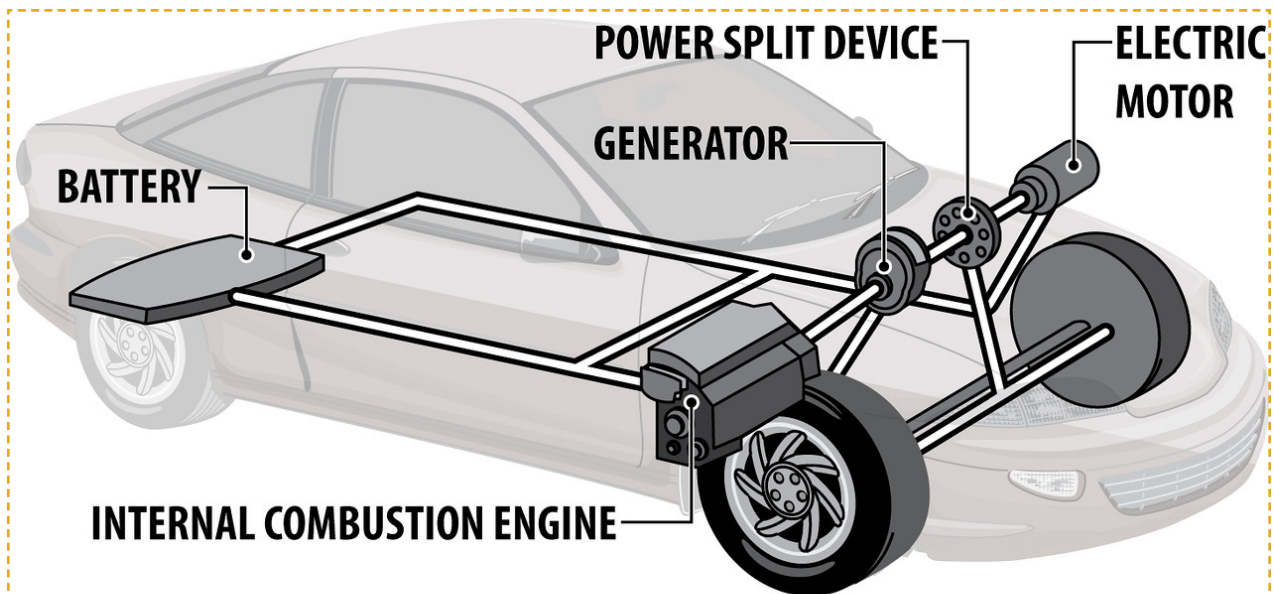
ALTERNATIVE FUELS INFORMATION STUDENT WORKSHEET - HYBRIDS: A GREAT COMBO



The hybrid electric vehicle, or HEV (hybrid means combination, or mixture), has a growing presence in the automotive market. HEVs have a gasoline engine and an electric motor with a battery. HEVs can run on the electric motor for short trips, using the gasoline engine for longer trips and higher speeds. HEVs on the market today have the same power and performance but can travel farther on one gallon of gas than gasoline-only vehicles.

When you drive an HEV, it feels the same as driving a regular car—except that there is very little noise when the electric motor is running the car. When you stop at a red light, for example, the gasoline engine shuts off. The car is totally quiet. When the light turns green and you step on the accelerator, the electric motor begins to move the car. The gasoline engine kicks in as you need more power and speed.

The battery that powers the electric motor is continually recharged by an on-board generator. The engine recharges the batteries whenever they are low. The regenerative braking system captures excess energy when the driver uses the brakes. This energy is also used to recharge the batteries.



Hybrid electric vehicles combine the benefits of gasoline engines and electric motors. Typically, the wheels are powered by an electric motor, and in some cases, the internal combustion engine assists. Hybrid electric vehicles do not need to be plugged in to charge the battery because they are charged by an onboard generator.

ENVIRONMENTAL IMPACTS



HEVs have significant environmental benefits. They reduce pollutants by one-third to one-half compared to conventional vehicles, because they use less fuel.

HYBRIDS TODAY AND TOMORROW



In 2006, there were nine hybrid models available to the general public. In 2016 over 4 million hybrids were registered with models available from almost every manufacturer and range from passenger cars to SUVs and pickup trucks. Today, hybrids make up 2.4 percent of all cars in the U.S.; however, hybrid sales are down in favor of electric vehicles (EVs). Electric vehicles make up about 5 percent of the new car market while hybrids—after experiencing a dip in sales in recent years—are up to 7 percent.⁴

PLUG-IN HYBRID ELECTRIC VEHICLES (PHEVS)

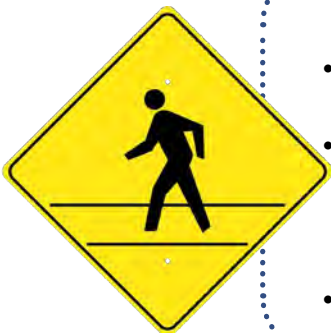


PHEVs are very similar to HEVs. They have an internal combustion engine, an electric motor, and a large battery pack. The larger battery pack in the PHEV gives it a range of 10-40 miles on an electric-only range. When the battery is depleted, the car continues to operate as a hybrid or gasoline vehicle.

The battery pack in a PHEV can be recharged by plugging it into a regular 120-volt electric outlet. People using a PHEV in an urban setting may be able to make their daily commute using all-electric power and then recharge the battery overnight to be ready for the next day's commute.

In 2019, there were only a few PHEV models available on the market (approximately 25), but more were expected to be available. As of September 2022, there are 34 PHEVs available in the U.S. market.

ADDITIONAL RESOURCES



- U.S. Energy Information Administration: www.eia.gov
- Alternative Fuels Data Center: <http://www.afdc.energy.gov/>
- U.S. Environmental Protection Agency: Transportation, Air Pollution, and Climate Change: <https://www.epa.gov/air-pollution-transportation>
- EVAdoption: <https://evadoption.com/ev-models/available-phevs/>

4. The New York Times (2022, August 5). "After Losing Favor to Electric Cars, Plug-In Hybrids Gain Ground." Available at: <https://www.nytimes.com/2022/08/05/business/plug-in-hybrid-electric-cars.html>.



ALTERNATIVE FUELS INFORMATION STUDENT WORKSHEET - PLUGGING INTO ELECTRIC VEHICLES



In 1891, William Morrison of Des Moines, Iowa, built the first electric car. By the turn of the century, there were twice as many electric vehicles (EVs) as gasoline-powered cars. There are over 40 different electric vehicle models from 21 manufacturers in the U.S. as of 2019. There are now over 1.5 million electric vehicles on roads in the U.S. Researchers are still working on the same problem experienced by those early electric vehicles—an efficient battery.

THE BATTERY IS THE CHALLENGE



Electric vehicles must have batteries that can be charged over and over again. Since most batteries can't store large amounts of electricity, an EV must carry as many batteries as possible. In some EVs, the batteries make up almost half the weight of the car. Today, batteries have warranties that guarantee them for a set time or mileage. For instance, most manufacturers warrant against failure for either eight years or 100,000 miles, but this varies by state.

The batteries limit the range of an EV—how far it can go on a charge. The more batteries an EV has, the more range it has, to a point. Too many batteries can weigh down a vehicle, causing it to use more energy. The typical EV can travel between 100 and 200 miles between charges, but some models can travel up to 400-500 miles. EVs can only go this far with perfect driving conditions. Weather, hills, and air conditioning can reduce the range. Even listening to the radio or turning on the lights can reduce the range. Research is being done to develop new batteries that will increase the range. These new batteries could double the range of EVs and last longer before they have to be replaced.

ENVIRONMENTAL IMPACTS



Electric vehicles produce no tailpipe emissions, but making the electricity to charge them can produce emissions. EVs are really coal, natural gas, nuclear, hydropower, and wind cars, because these fuels produce most of the electricity in the U.S. Coal alone generates almost half of U.S. electricity. When fossil fuels are burned, pollutants are produced like those from the tailpipe of a gasoline-powered car. Power plant pollution, however, is easier to control than tailpipe pollution. Emissions from power plants are controlled and monitored carefully. And power plants are usually located outside major cities.

MAINTENANCE



Many people like the low maintenance of electric vehicles. EVs need no engine tune-ups, oil changes, water pumps, radiators, injectors, or tailpipes. And no more trips to the service station. EVs can be recharged at home at night when electric rates are low, making the fuel cost about the same as gasoline. In 2019, there were 21,324 electric charging units at public refueling stations, allowing you to recharge at the airport, in a parking garage, or even while shopping at the mall. As of 2022, there are 48,142 charging station locations nationwide.

THE FUTURE OF EVS



Vehicles are rapidly developing, and, with the added technology of connected and autonomous cars, making a long-lasting battery that can deliver excellent mileage and connectivity is essential to EVs. In 2022, California made history when regulators agreed to ban the sale of new gasoline-fueled cars by 2035. This move by the state with the largest auto market in the country could spark similar motions across the nation. Some estimates forecast that electric vehicles will make up almost 60% of all global new car sales by 2040.⁵

ADDITIONAL RESOURCES



- U.S. Energy Information Administration: www.eia.gov
- Alternative Fuels Data Center: <http://www.afdc.energy.gov/>
- U.S. Environmental Protection Agency: Transportation, Air Pollution, and Climate Change: <https://www.epa.gov/air-pollution-transportation>

3. Bloomberg New Energy Finance (2016, February 25). "Electric Vehicles to be 35% of Global New Car Sales by 2040." Available at: <https://about.bnef.com/press-releases/electric-vehicles-to-be-35-of-global-new-car-sales-by-2040/>.



ALTERNATIVE FUELS INFORMATION STUDENT WORKSHEET - ETHANOL: FROM FIELD TO FUEL



Ethanol is a clear, colorless fuel made from the sugars found in plants. Ethanol can be blended with gasoline to reduce pollution from the tailpipes of vehicles. In the U.S., ethanol is usually made from corn. Today, many ethanol plants, mostly in the Midwest, produce over ten billion gallons of ethanol a year.

There are several processes that can produce alcohol (ethanol) from biomass. The most commonly used processes today use yeast to ferment the sugars and starch in the feedstock to produce ethanol. A new process breaks down woody fibers, so we can make ethanol from trees, grasses, and crop wastes. Trees and grasses need less energy than grains, which must be replanted every year.

Scientists have developed fast-growing trees that grow to size in ten years. Many grasses can produce two harvests a year for many years.

ETHANOL AS A TRANSPORTATION FUEL



Most of the ethanol fuel used today is E10. The letter E stands for ethanol, and the number stands for the percent of ethanol that is mixed with gasoline. E10 is 10 percent ethanol and 90 percent gasoline. E10 is the most popular ethanol blend sold in the U.S. because E10 can be used without making any changes to engines built for gasoline. You will often see stickers at the gas pump telling you that the gas may contain up to 10 percent ethanol.

When we add small amounts of ethanol to gasoline (up to 10 percent), there are many advantages. It reduces the pollution from the tailpipes of vehicles, making the air cleaner. It keeps engines running smoothly without the need for lead or other dangerous chemicals. Ethanol is produced from crops grown in the United States; it is a domestic fuel. Over ninety percent (90%) of the ethanol produced in the United States today is mixed with gasoline to make E10.

There are also cars that are designed to run on higher ethanol blends. These cars are called flexible fuel vehicles (FFVs). They can use any blend of ethanol fuel from E10 to E85. Gasoline that contains 85 percent ethanol or more is considered an alternative fuel. While there are an estimated twenty million FFVs in the United States today, many flexible fuel vehicle owners don't realize their car is a FFV. In addition, many FFVs don't have access to E85. There are just over 3,354 fueling stations with E85 pumps in the U.S.. This number is expected to keep rising in the next few years.

Ethanol can be mixed with diesel as a fuel for trucks and buses that usually run on diesel. It can also be used instead of leaded gasoline in small planes. In addition, ethanol is being tested as a fuel to produce hydrogen for fuel cell vehicles.

ENVIRONMENTAL IMPACT



Ethanol is made from crops that absorb carbon dioxide and give off oxygen. This carbon

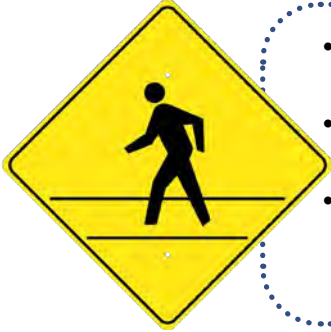
cycle maintains the balance of carbon dioxide in the atmosphere when using ethanol as a fuel.

FUTURE OF ETHANOL



Using ethanol as a fuel helps farmers by providing additional uses for their crops. Ethanol is a cleaner fuel than gasoline; it makes the air healthier to breathe. Using ethanol also means we don't have to import as much petroleum from other countries.

ADDITIONAL RESOURCES



- U.S. Energy Information Administration: www.eia.gov
- Alternative Fuels Data Center: <http://www.afdc.energy.gov/>
- U.S. Environmental Protection Agency: Transportation, Air Pollution, and Climate Change: <https://www.epa.gov/air-pollution-transportation>



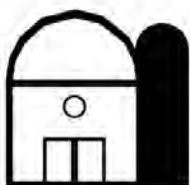
ALTERNATIVE FUELS INFORMATION STUDENT WORKSHEET - PROPANE: NOT JUST FOR GRILLING



Propane is an energy-rich fossil fuel that is sometimes called liquefied petroleum gas (LPG). It is colorless and odorless; a smell is added to serve as a warning agent. Propane comes from petroleum refining and natural gas processing. Like all fossil fuels, it is nonrenewable.

Under normal conditions, propane is a gas. When propane is put under pressure or cooled to a lower temperature, however, it changes into a liquid and can be stored in tanks. Propane takes up 270 times less space as a liquid than it does as a gas, making it a portable fuel.

Propane Uses



To heat barns and
operate farm equipment



To make products
and fuel industry



To fuel hot air
balloons



To fuel machinery
that is used indoors



To fuel backyard grills



To heat homes



To fuel fleet vehicles



To fuel appliances

PROPANE A TRANSPORTATION FUEL



Transportation accounts for nearly three-fourths of total U.S. petroleum consumption. It is commonly used as an alternative fuel for fleet vehicles like taxicabs, government vehicles, and school buses. Fleets are groups of vehicles that have their own fuel stations. For fleet vehicles, the cost of using propane is less than gasoline. Propane is a good engine fuel because it burns cleaner than gasoline. The engine stays clean, lasts longer, and doesn't need as much service. Vehicles can go as fast using propane and carry as much cargo as gasoline-powered cars.

Why is propane not used in more personal vehicles? We can find propane in most areas of the country, but it is not as convenient as gasoline. There are only 1,263 propane-fueling stations in the U.S. A regular car has to be modified (changed) to use propane, which can cost between \$4,000 to \$12,000.

ENVIRONMENTAL IMPACTS



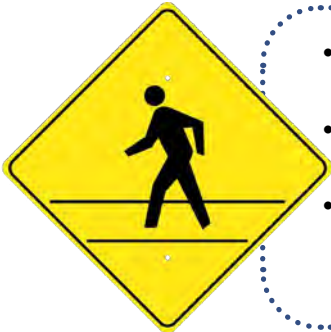
Propane engines produce less air pollution than gasoline. Carbon monoxide emissions from propane vehicles are 20 to 90 percent lower and hydrocarbon emissions are 40 to 80 percent lower than gasoline engines.

FUTURE OF PROPANE



Propane will mostly be used for fleet vehicles in the future. If you get a job at a company that has its own fleet, you may very well be driving a propane vehicle.

ADDITIONAL RESOURCES



- U.S. Energy Information Administration: www.eia.gov
- Alternative Fuels Data Center: <http://www.afdc.energy.gov/>
- U.S. Environmental Protection Agency: Transportation, Air Pollution, and Climate Change: <https://www.epa.gov/air-pollution-transportation>



ALTERNATIVE FUELS INFORMATION STUDENT WORKSHEET - CNG/LNG: A NATURAL FOR VEHICLES



The natural gas we use for heating, cooking, clothes drying, and water heating can also be a cleaner burning transportation fuel when compressed (put under pressure). Natural gas vehicles burn so cleanly that they are used to carry TV cameras and reporters ahead of the runners in marathons. Natural gas is a nonrenewable fossil fuel with plentiful supplies in the United States.

CNG—COMPRESSED NATURAL GAS

Natural gas is an energy-rich fossil fuel. It burns cleaner than gasoline, producing 20-30% fewer greenhouse gas emissions and 95% fewer tailpipe emissions. Natural gas is also less expensive than gasoline. To use natural gas in vehicles, it is put in tanks under pressure. Even under pressure, it only has about a third as much energy as gasoline. As a result, natural gas vehicles have a shorter range or distance they can travel on one tank of fuel. If more tanks are added, the vehicle gets heavy and can't go as far.

Some people worry about using CNG because natural gas is flammable. Manufacturers make CNG tanks stronger than normal gasoline tanks. The fuel tanks are harder to damage in crashes than gasoline tanks. If a fuel line breaks, the natural gas will rise into the air gasoline which forms flammable puddles. Also, natural gas catches fire at a much higher temperature than gasoline, making it more difficult to catch fire.

Today, there are only about 815 natural gas fueling stations in the United States. Natural gas vehicles are good as fleet vehicles with their own fueling stations. Many businesses with CNG fleets say their vehicles last longer because the fuel is so clean burning.

ENVIRONMENTAL IMPACTS

Natural gas is a cleaner-burning fossil fuel. Compressed natural gas vehicles produce fewer emissions than gasoline-powered vehicles. They are good to use in areas with air pollution problems.

CNG VEHICLES TODAY AND TOMORROW

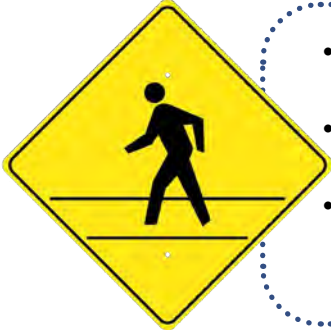
Today, there are about 250,000 natural gas vehicles in the U.S., mostly in the South and West. About half of the vehicles are privately owned, and half are owned by government agencies. The National Petroleum council estimates that if diesel prices continue to increase, 40% of all new heavy trucks will run on natural gas by 2025.

LNG—LIQUEFIED NATURAL GAS

There are about 3,400 vehicles in the U.S. that run on LNG—natural gas that is turned into a liquid by cooling it to -259°F . Most LNG vehicles are government-owned. There are 83 LNG-fueling stations as of 2016. The advantage of LNG is that natural gas takes up much

less space as a liquid than as a gas, so the tanks can be much smaller. The disadvantage is that the fuel tanks must be kept cold, which uses more fuel.

ADDITIONAL RESOURCES



- U.S. Energy Information Administration: www.eia.gov
- Alternative Fuels Data Center: <http://www.afdc.energy.gov/>
- U.S. Environmental Protection Agency: Transportation, Air Pollution, and Climate Change: <https://www.epa.gov/air-pollution-transportation>



ALTERNATIVE FUELS INFORMATION STUDENT WORKSHEET - FROM BIOHAZARD TO BIOMASS



Biomass is a renewable source of energy made from organic material that comes from plants and animals. Biomass contains stored energy from the sun. For instance, using photosynthesis, plants absorb the sun's energy. When biomass is burned, the chemical energy in biomass is released as heat. Biomass can be burned directly or converted to liquid biofuels or biogas that can be burned as fuels (similar to ethanol).

Examples of biomass and their uses for energy:

- Wood and wood-processing wastes—burned to heat buildings, to produce heat in industry, and to generate electricity
- Agricultural crops and waste materials—burned as a fuel or converted to liquid biofuels
- Food, yard, and wood waste in garbage—burned to generate electricity in power plants or converted to biogas in landfills
- Animal manure and human sewage—converted to biogas, which can be burned as a fuel

TURNING SEWAGE INTO FUEL



Process 1: In a process termed “hydrothermal liquefaction,” scientists recreate the geological conditions that create oil deep underground. By taking sewage and subjecting it to extreme heat temperatures and pressures, what took millions of years can occur in a matter of minutes.

The process creates a biocrude (like crude oil) that can then be refined to yield fuels similar to gasoline, diesel, and jet fuels. Also, because biofuel from these waste products has an energy output more similar to gasoline, existing vehicles would not require expensive modifications.

Process 2: Policy makers are interested in collecting methane gas from dairy farms that use a manure-lagoon to collect the cows' waste. Farmers would do this by using a methane digester, a machine that captures methane gas from the manure and converts it into usable/renewable electricity.

California farmer Albert Straus of Straus Family Creamery, powers his farm largely on the electricity produced from his digester.

Process 3: This same methane can also be used to power fuel cells, which generate electricity that can then be fed back to the main grid. Human waste can also be used for this by using an anaerobic digester instead of a methane one, these are already in use in some parts of the country to generate heat and electricity.

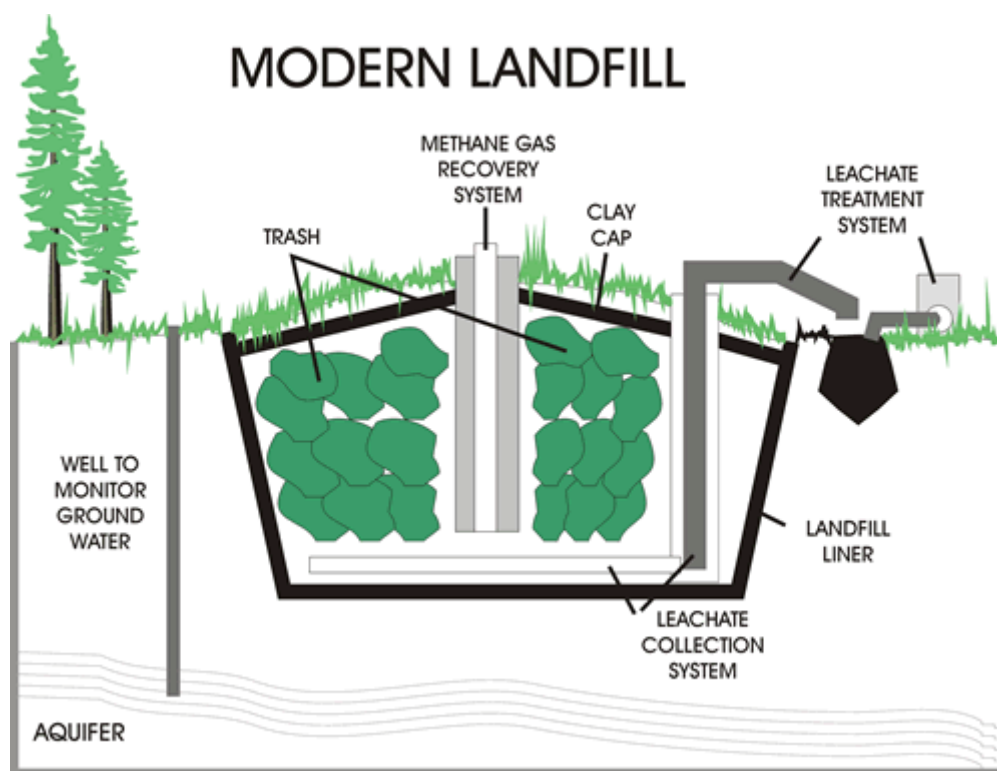
ENVIRONMENTAL IMPACTS

While biomass is a renewable resource, it does still produce gasses, like methane, that pollute the air, since capturing the methane is not yet a perfect process.

MORE TO MANURE

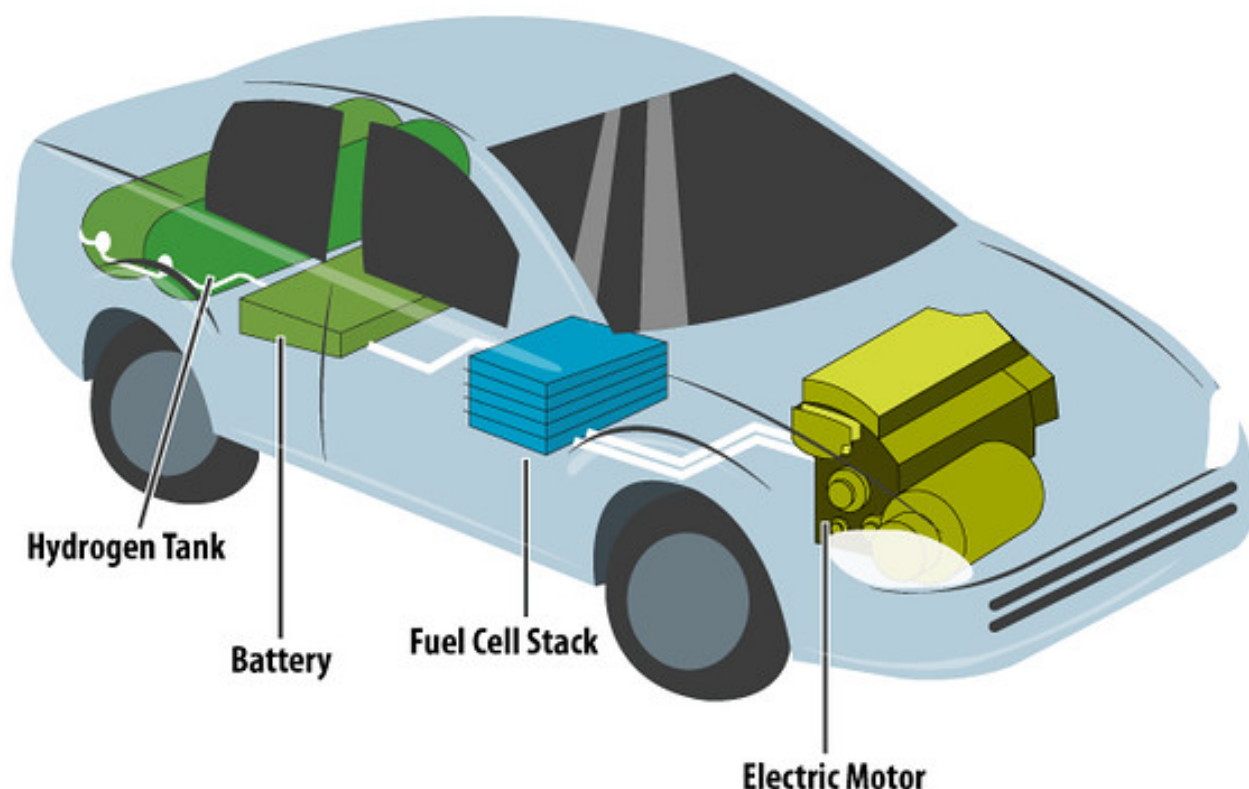
In 2010, an Indiana farmer at Fair Oaks Farms began converting its cow and pig manure into low-emission natural gas fuel and electricity using the product to power its facilities and fleet of trucks.

In 2017, Toyota announced its plans for California's biggest cow-to-car project by 2020, creating a powerplant that uses methane emissions from dairy farms to generate enough electricity to power 2,350 homes or enough fuel to power 1,500 vehicles. Other countries have joined the efforts, and in 2022, one farm in Italy built a structure to extract bio-methane from animal waste on-site right along with a fueling station. Such a system where animal byproducts are converted and delivered through only a few meters of pipe hold promise for a more sustainable future.





ALTERNATIVE FUELS INFORMATION STUDENT WORKSHEET - ROAD TO THE FUTURE: HYDROGEN FUEL CELLS



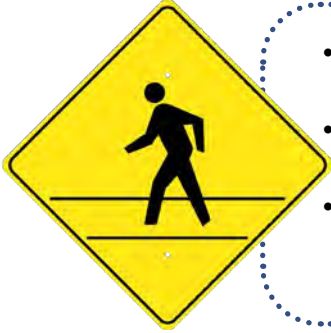
Hydrogen is the most abundant element in the universe, but it doesn't exist on Earth as a gas. We have to make it from other materials. One way is to split water molecules apart—into hydrogen and oxygen. Another is to break down molecules of natural gas, biomass, or coal. Fuel cells use hydrogen and oxygen to produce electricity without harmful emissions; water is the main by-product. Hydrogen is a gas at normal conditions, which makes it harder to move and store than liquid fuels. We have no widespread system today to move and store it.

There are few fuel cell vehicle models available in the U.S. The most well known are the Honda Clarity, Hyundai Tucson, and Toyota Mirai. However, several makers have unveiled their prototypes for 2020, including luxury brands like Audi, Lexus, and BMW. Their availability is quite limited, and there are only 54 hydrogen fueling stations nationwide as of 2022, mainly in California. Hydrogen fuel cells use hydrogen and oxygen to make electricity without harmful emissions, instead water is the main by-product.

Today, it costs a lot to make hydrogen fuel, but research is underway to find better ways to produce and use it. The biggest obstacle to widespread use will be storage. The low

energy content of hydrogen will require fuel tanks six times larger than gasoline tanks. Its environmental benefits, however, mean that in the future, hydrogen fuel cell vehicles may be a common sight on the roadways of America. The U.S. Department of Energy is supporting hydrogen fuel cell research because hydrogen is such a clean and abundant fuel.

ADDITIONAL RESOURCES



- U.S. Energy Information Administration: www.eia.gov
- Alternative Fuels Data Center: <http://www.afdc.energy.gov/>
- U.S. Environmental Protection Agency: Transportation, Air Pollution, and Climate Change: <https://www.epa.gov/air-pollution-transportation>

TRANSPORTATION FUELS STUDENT ACTIVITY GUIDELINES

In groups, you will learn about a specific transportation fuel and present what you have learned to your class. The focus is on fuels used primarily by cars and trucks, as well as buses.

1. Read the “Alternative Fuels Information Student Worksheet – Background” to learn some background information about transportation fuels, particularly the role of petroleum and why people are looking at alternative sources of fuel.
2. Read the “Alternative Fuels Student Information Worksheet” for the fuel your group has been assigned (e.g. gasoline, diesel, biodiesel, etc.).
3. As a group, develop a list of facts that you want to teach your class about your fuel. In addition to the Information Worksheet, you may want to consult some additional resources, either those listed on the worksheet or other resources identified by your teacher. Here is a list of questions to help you gather information:
 - Is your fuel renewable or nonrenewable?
 - How is your fuel made?
 - Is your fuel available in your area? (hint: consider looking at the Department of Energy’s Alternative Fuel Station Locator at: <http://energy.gov/maps/alternative-fueling-station-locator>)
 - What types of vehicles can use your fuel? (check out www.fueleconomy.gov for information about what cars used alternative fuels)
 - What are the costs associated with your fuel?
 - What are the challenges to developing a widespread market for your fuel?
 - Would you buy a vehicle that uses your fuel? Why or why not?
4. Prepare a visual aid with information about your fuel. Your teacher will provide additional information about the size and specific contents for your visual aid. Write them down here:
5. Prepare a short oral presentation for your class about your fuel. Your teacher will provide additional information about the size and specific contents for your presentation. Write them down here:

Lesson 4: Our Class Transportation Carbon Footprint⁶

Description

Students will learn to measure, analyze, and interpret transportation data. They will better understand the impact of their transportation choices on CO₂ emission levels. The term “CO₂ footprint” is introduced and students will consider how to reduce their CO₂ footprint with regard to getting to and from school.

Learning Outcomes

Students will be able to:

- Measure the CO₂ emissions produced by a classroom of students getting to and from school
- Analyze their personal as well as their class's contribution to CO₂ emissions
- Brainstorm ways to reduce their CO₂ footprint, both as individuals and as a class



Lesson Time

- 30 minutes to calculate and collect all the data
- 20 minutes to answer general questions and discuss results

STANDARDS AND OBJECTIVES

Next Generation Science Standards

- **MS-ESS3-1 Earth and Human Activity.** Connections to Engineering, Technology, and Applications of Science Influence of Science, Engineering, and Technology on Society and the Natural World
 - All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment

Materials

- Transportation Carbon Footprint Student Worksheet (one per student)
- School population data (how many students attend your school)

4. This lesson is adapted from the Class Transportation Survey developed for the Cool School Challenge sponsored by the National Wildlife Federation. More information can be found at: <http://www.greeneducationfoundation.org/institute/lesson-clearinghouse/503-Class-Transportation-Survey.html>.

- Transportation Carbon Footprint Summary table
- Transportation Carbon Footprint General Questions handout

Instructional Activity

1. Lead a discussion using the “Introduction” to this lesson. You may find it useful to review additional online sources such as “Greenhouse Gas Emissions” from the U.S. Environmental Protection Agency at <https://www.epa.gov/ghgemissions>.
2. Have each student complete the Transportation Carbon Footprint Student Worksheet. You may want to ask students to complete steps 1 and 2 of the assignment worksheet in advance. All students will answer the first three questions. Then, depending on how the student travels to/from school, the student will follow the set of questions from Sections A-D, accordingly.
3. Summarize each student’s estimate of the individual lbs CO₂ emitted per person per year in the “Transportation Carbon Footprint Summary” sheet (this sheet could be written on the board, or presented using an overhead project, or other display means depending on your classroom).
4. Use the “Transportation Carbon Footprint General Questions” to lead a discussion with your students about their transportation carbon footprint. The questions can be modified to accommodate specific circumstances in your school/classroom.
5. Additional Information: if a student travels to school using one mode (e.g. carpool), and then back home using a different mode (e.g. bus), it will be necessary to slightly modify the approach used to calculate the carbon footprint. For example, instead of starting with roundtrip distance, start with one-way distance and then follow the steps in each relevant section to calculate the one-way carbon footprint and then add the two results together. This can also be a great add-on activity for the students requiring quantitative problem solving if you provide some example scenarios. You can even consider adding in extra trips such as a detour to an after-school activity, etc.

Additional Activities

1. Students complete a “think, pair, and share” activity. Ask students to 1) think about something that surprised them or that they want to know more about, 2) pair with another student, and 3) share these ideas.
2. Students reflect on their data in a written form via a poem, vignette, etc. They can use what they have learned as inspiration or the teacher can assign a more specific prompt.

3. Students can use cotton balls to represent a unit of CO₂. They can create a group visual with the cotton balls - perhaps a large poster on butcher paper with a large bus or several cars with cotton balls coming out of the exhaust pipes. This would be a way to visualize their carbon footprint.
4. Students can outline their feet on a piece of paper and color in a portion to represent their CO₂. All the footprints can then be displayed together on the classroom wall as their collective footprint.

Connected vehicles with crash avoidance technology could address 80% of crashes involving unimpaired drivers.

TRANSPORTATION CARBON FOOTPRINT STUDENT WORKSHEET

INTRODUCTION



Roughly one-quarter of U.S. greenhouse gas emissions come from the transportation sector: trains, planes, boats, trucks, cars, etc.⁷ Choices made everyday about how to get to school, work, the mall, etc., directly impact the size of your CO₂ “footprint.”

Your CO₂ “footprint” is basically a measurement of how much carbon dioxide is emitted into the atmosphere as a result of an individual’s consumption of fossil fuels. Transportation choices are just one component of a CO₂ footprint – but can often be the most significant.

How big is your transportation footprint? And how does it compare with that of your classmates?

Through this activity you’ll conduct a survey to identify the different modes of transportation you and your classmates use to get to and from school. You’ll then use this information to calculate the combined impact of those choices on your CO₂ footprint.

ASSIGNMENT STEPS

1. Find out the round trip distance from your home to school. You can either do this by noting the mileage while doing the journey or go to an online map program (e.g. maps.google.com) and put in the correct addresses to calculate the distance.

Roundtrip distance to and from school: _____ Miles

2. If you travel to and from school in a car (either alone or in a carpool), determine the average fuel economy of that vehicle in miles per gallon by checking www.fueleconomy.gov. (Hint: use the Find a Car feature and enter the year, make, and model to get the fuel economy.) Write that information below.

Fuel economy: _____ Miles per gallon

5. U.S. Environmental Protection Agency, 2016. “Sources of Greenhouse Gas Emissions.” Accessed October 20, 2016 from <https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions>.

3. How do you typically get to and from school? In the table below, find the option which best fits your mode of transportation and then complete the relevant section.

If you get to and from school by...	Complete the following section:
Car, driving alone	Section A
Carpool – with other students from your school	Section B
Bus – public or school bus	Section C
Micromobility- electric scooter, bike, unicycle, etc.	Section D
Walk, bike, or other zero-emission mode	Section E

SECTION A: TRANSPORTATION = CAR, DRIVING ALONE



Complete the following:

1. Estimate gallons of gas consumed each day getting to and from school. Show your work.

Answer: _____ gallons of fuel consumed

2. Calculate the CO_2 emissions of your commute. Each gallon of gasoline burned emits 20 lbs of CO_2 . Show your work.

Answer: _____ lbs CO_2 emitted getting to and from school

3. Estimate your annual CO_2 emissions from getting to and from school. Multiply your total from #2 above by 180 school days. Show your work.

Answer: _____ lbs CO_2 emitted getting to and from school

4. Estimate your CO_2 footprint of your school from transportation. What if every student at your school produced the same amount of CO_2 as you, just by getting to and from school? What would your school's CO_2 footprint from transportation be? Multiply your answer from #3 by the number of students at your school. Show your work.

Answer: _____ lbs CO_2 generated per year by the whole school

SECTION B: TRANSPORTATION = CARPOOL



Complete the following:

1. Estimate gallons of gas consumed each day getting to and from school. Show your work.

Answer: _____ gallons of fuel consumed

2. Calculate the CO₂ emissions of your commute. Each gallon of gasoline burned emits 20 lbs of CO₂. Show your work.

Answer: _____ lbs CO₂ emitted getting to and from school

3. Calculate your individual impact. How many people shared your ride? Divide your total from #2 by the number of people in your carpool (include yourself!) to calculate the individual CO₂ emissions of each person in the carpool. Only include students from your school in your carpool calculation. Do not include others (e.g. driver, siblings at other schools, etc.).

Answer: _____ lbs CO₂ emitted per person

4. Estimate your annual CO₂ emissions from getting to and from school. Multiply your total from #3 above by 180 school days. Show your work.

Answer: _____ lbs CO₂ emitted per person per year

5. Estimate your CO₂ footprint of your school from transportation. What if every student at your school produced the same amount of CO₂ as you, just by getting to and from school? What would your school's CO₂ footprint from transportation be? Multiply your answer from #4 by the number of students at your school. Show your work.

Answer: _____ lbs CO₂ generated per year by the whole school

SECTION C: TRANSPORTATION = BUS (PUBLIC OR SCHOOL BUS)



Complete the following:

1. Estimate the amount of fuel used by the bus. Buses get about 5 miles per gallon of diesel. Calculate the gallons of diesel used by the bus. Show your work.

Answer: _____ gallons of fuel consumed

2. Calculate the CO₂ emissions of your commute. Each gallon of diesel burned emits 22 lbs of CO₂. Calculate the amount of CO₂ generated by the bus for each roundtrip journey. Show your work.

Answer: _____ lbs CO₂ emitted getting to and from school

3. Calculate the CO₂ emissions per passenger. How many people shared your ride? Estimate the number of students who rode the bus with you today. Then calculate the CO₂ lbs emitted per passenger on the bus. Show your work.

Answer: _____ lbs CO₂ emitted per person

4. Estimate your annual CO₂ emissions from getting to and from school. Multiply your total from #3 above by 180 school days. Show your work.

Answer: _____ lbs CO₂ emitted per person per year

5. Estimate your CO₂ footprint of your school from transportation. What if every student at your school produced the same amount of CO₂ as you, just by getting to and from school? What would your school's CO₂ footprint from transportation be? Multiply your answer from #4 by the number of students at your school. Show your work.

Answer: _____ lbs CO₂ emitted per year by the whole school

SECTION D: TRANSPORTATION = MICROMOBILITY (ELECTRIC SCOOTER, BIKE, ETC.)



Complete the following:

1. Estimate how much CO₂ charging your device costs. A shared electric scooter, on average, takes 6 hours to fully charge and has the battery power to be ridden for 20 miles. This equates to a charge time of 18 minutes per mile. Combined with the 487.37 (little more than 1 lbs.) grams of CO₂ emitted per kilowatt-hour, the electricity needed to charge a scooter per mile results in the release of 146.21 grams (.32 lbs) of CO₂. Show your work.

Answer: _____ lbs of CO₂ emitted getting to and from school

2. Estimate your annual CO₂ emissions from getting to and from school. Multiply your total from #3 above by 180 school days. Show your work.

Answer: _____ lbs CO₂ emitted per person per year

3. Estimate your CO₂ footprint of your school from transportation. What if every student at your school produced the same amount of CO₂ as you, just by getting to and from school? What would your school's CO₂ footprint from transportation be? Multiply your answer from #2 by the number of students at your school. Show your work.

Answer: _____ lbs CO₂ emitted per year by the whole school

SECTION E: TRANSPORTATION = WALK, BIKE, SKATEBOARD, OR OTHER
EMISSION-FREE MODE OF TRANSPORT

Your CO₂ footprint equals zero!

**If everyone in your school traveled as you did today,
this part of the CO₂ school footprint would be zero!**



[illegible]

[illegible]

CLASS TRANSPORTATION SURVEY GENERAL QUESTIONS

1. What is the most common way students in your class get to and from school? Why do you think this is the case?
2. Which mode of transportation generates the most CO₂ per person in your class?
3. How many students generated “zero” pounds of CO₂ from their commutes?
4. Looking at the Class Transportation Data Summary, how many students in your class ride the bus to and from school?
5. What might be some ways to increase bus ridership?
6. Looking at the Class Transportation Data Summary, how many students in your class walk or bike to and from school?
7. What might be some ways to increase walking and biking to school?
8. If you do not currently walk or bike to school, would you consider either of these options as possible for you? Why or why not?
9. Looking at the Class Transportation Data Summary, how many students in your class carpool to and from school?
10. What might be some ways to increase carpooling to school?
11. How might your class decrease its transportation CO₂ footprint?

Lesson 5: Pretzel Power - Exploring Fuel Efficiency⁸

DESCRIPTION

In this lesson, students will learn about the energy efficiency of different kinds of vehicles and the benefits of carpooling.

LEARNING OUTCOMES

Students will be able to:

- Compare fuel efficiency across different vehicles
- Calculate how much gas is needed to travel a specific distance depending on fuel efficiency



LESSON TIME

- 1 class period

STANDARDS AND OBJECTIVES

Next Generation Science Standards

- **MS-ESS3-1 Earth and Human Activity.** Connections to Engineering, Technology, and Applications of Science Influence of Science, Engineering, and Technology on Society and the Natural World
 - All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment

MATERIALS

- 3" x 5" index cards
- Internet access for students
- Bag of pretzels
- Plastic sandwich bags
- Three signs (Home, Near Town, Far Town)
- Automobile Cards

6. This lesson is adapted from the Elementary Transportation Fuels Infobook developed by the National Energy Education Development Project. The complete resource can be found at: <http://www.need.org/files/curriculum/guides/ElementaryTransportationFuelsInfobook.pdf>

INSTRUCTIONAL ACTIVITY

Prepare the following:

- Prepare a plastic bag with 10 pretzels for each student.
- Make three signs: one labeled “Home,” one labeled “Near Town,” and one labeled “Far Town.” The signs should be large enough to see from across the room.
- Select a large area and place the Home, Near Town, and Far Town signs on poles or walls. The distance from Home to Near Town should be approximately 50 student steps. The distance to Far Town should be approximately 100 student steps. (Do not give these distances to students.)

For the activity, have students choose an automobile from the “Car Lot” table in this curriculum guide and write down their stats on an index card. Alternatively, students can look up a car they would like to drive on www.fueleconomy.gov. On 3” x 5” cards, students should record the car’s name, model year, and combined miles per gallon.

Next, distribute the bags of pretzels to each student. Tell students not to eat the pretzels until they are told to. Explain to the students that each pretzel represents one gallon of gasoline, and each step (heel-to-toe) the student takes represents one mile traveled.

Students should next calculate how many steps they can take for each gallon of gasoline (i.e. pretzel) consumed. For example, a 2012 Audi A3 (see pre-made automobile cards) has a combined MPG of 34. Therefore, each pretzel would allow the student to take 34 steps.

The activity takes place in two rounds.

The transportation sector is the second-biggest source of greenhouse gasses (GHGs) in the U.S.

ROUND ONE

Use only 5 pretzels (maximum) for this round. Each student will use their car's combined MPG and attempt to travel from "Home" to "Near Town" and back. If anyone runs out of fuel (i.e. pretzels), he/she must stay at that point until round one is over. Line up at "Home" and start stepping!

Discuss with the students:

- Which cars got you to work and home? Which didn't?
- Did anyone have extra fuel remaining?
- What alternatives to driving your own car are there?

ROUND TWO

Using the remaining five pretzels, have students travel from “Home” to “Far Town” using the same basic instructions as for Round One (i.e. each pretzel is one gallon of gas and the combined MPG is how many steps the student can take for each pretzel). But in this round, allow the students to negotiate and combine pretzels for fuel. Just remember to take into consideration the number of passengers the vehicle can accommodate – a compact car can’t carry as many people as a van, for example.

Discuss with the students:

- Who made it to “Far Town” and back? How did you do this?
- Who did not make it to “Far Town” and back? Why not?

(OPTIONAL) ROUND THREE

Now that students have learned about fuel and pollution, they have a better understanding of the benefits of carpooling. Creating a Public Service Announcement of its benefits can be an optional group activity. Public Service Announcements, or PSAs, are videos created to raise awareness and change public attitudes and behavior toward a social issue. Effective PSAs often have a powerful message that resonates with the viewer.

In groups, ask students to:

1. Determine ONE message they want to communicate in their PSA
2. Determine the intended audience of their PSA
3. Determine the tone and persuasive tactic to communicate their message, whether the video would use positive or negative reinforcement to spark a behavioral change
4. Capture a 2-minute video that applies their ideas

THE CAR LOT

Record each student's data in the table below and add up the CO₂ emissions for the entire class.

	EPA Class	Vehicle	Combined Miles Per Gallon (MPG)
1	Two-seater	Smart EQ for two (coupe) (EV)	108
2	Minicompact	Fiat 500e (EV)	112
3	Subcompact	BMW i3s (EV)	113
4	Compacts	Volkswagon e-Golf (EV)	119
5	Midsize	Hyundai Ioniq Electric (EV)	136
6	Large	Tesla Model S Long Range (EV)	111
7	Fuel-economy	Toyota Prius Prime (EV)	133
8	Sml. Station Wagon	Chevrolet Bolt (EV)	119
9	Midsize Station Wagon	Volvo V90 FWD	27
10	Two-seaters	Bugatti Chiron, Lamborghini Aventador Coupe, Lamborghini Roadster	11
11	Minicompact	Ferrari GTC4Lusso	13
12	Subcompact	Roush Performance Stage 3 Mustang	15
13	Compacts	Rolls-Royce Dawn	14
14	Midsize	Bentley Mulsanne	12
15	Large	Rolls-Royce Ghost, Rolls-Royce Phantom	14
16	Sml. Station Wagon	Buick Regal TourX AWD	24
17	Midsize Station Wagon	Rolls-Royce Cullinan	14

Lesson 6: Moving Beyond the Automobile – Film Guides⁹

DESCRIPTION

In this lesson, students will watch a series of short videos produced by Streetfilms.org and engage in a class discussion about different forms of transportation.

Additional note to teachers: Students can be split up into smaller groups for this lesson. Each group can be given a question to answer from each film. After a reasonable amount of discussion time, a representative from each group can read the question to the class and do a “mini” presentation of the group’s response.

LEARNING OUTCOMES

Students will be able to:

- Identify the benefits and drawbacks of three forms of transportation alternatives



LESSON TIME

- 1 class period

STANDARDS AND OBJECTIVES

Next Generation Science Standards

- **MS-ESS3-1 Earth and Human Activity.** Connections to Engineering, Technology, and Applications of Science Influence of Science, Engineering, and Technology on Society and the Natural World
 - All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment

California Common Core Standards

- **Writing Standards (Grades 6–12).** Write arguments to support claims with clear reasons and relevant evidence.
- **Speaking and Listening Standards (Grades 6–12).** Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on texts, and issues, building on others’ ideas and expressing their own clearly.

7. This lesson is adapted from a curriculum guide developed by Streetfilms.org as part of their “Moving Beyond the Curriculum” program. The complete program, including links to all films is available at: <http://www.streetfilms.org/moving-beyond-the-automobile/curriculum/>

MATERIALS

- Internet access to watch the following short (3-4 min) films by Streefilms.org and The Redford Center
 - Bus Rapid Transit: <https://www.youtube.com/watch?v=YGxr2l0cUvM>
 - Bicycling: Bicycling: https://www.youtube.com/watch?v=OB_hkWKH7NA
 - Car Sharing: <https://www.youtube.com/watch?v=-Ef9helWgy4>
 - Transportation and Happiness: <https://vimeo.com/732542898>

INSTRUCTIONAL ACTIVITY

Arrange to view each of the four films and then facilitate a discussion with students using the questions posed below. The films are short (3-4 minutes each). They could be assigned as homework or could be viewed during class.

The forms of transportation illustrated in these films (bus rapid transit, cycling, and carsharing) have potential as alternatives to reliance on single-occupancy vehicles. These are also considerably more sustainable ways of getting around. Each has different benefits and drawbacks, which can be discussed as a class.

BUS RAPID TRANSIT ([HTTPS://WWW.YOUTUBE.COM/WATCH?V=YGXR2L0CUVM](https://www.youtube.com/watch?v=YGXR2L0CUVM))

Synopsis: BRT provides faster, more reliable bus service, and has the potential to meet more remote locations in a city. BRT advantages often include exclusive lanes for bus-only use, special waiting stations up on a platform with advance payment, and buses are given priority at intersections.

- What are the critical components that distinguish Bus Rapid Transit (BRT) from regular bus service?
- Where are the best Bus Rapid Transit Systems in the world?
- What are the benefits of Bus Rapid Transit?
- How is BRT less expensive than building other forms of public transit, like a subway, for example?
- Why is it important to improve bus ridership?
- What are some of the problems with buses in your community?
- What changes do you think would make bus riding more popular? Would BRT be a good option?

CARSHARING ([HTTPS://WWW.YOUTUBE.COM/WATCH?V=-EF9HELWGY4](https://www.youtube.com/watch?v=-EF9HELWGY4))

Synopsis: Carsharing reduces the number of car trips an individual takes and allows people to avoid buying a car. It also encourages transit ridership, walking, and biking, except at times when a car is necessary.

- What are the personal benefits of carsharing or ridesharing?
- What are the shared benefits of carsharing or ridesharing?
- How has carsharing been incorporated into public transportation systems?
- How do cities support car sharing?

BICYCLING & MICROMOBILITY ([HTTPS://WWW.YOUTUBE.COM/WATCH?V=OB_HKWKH7NA](https://www.youtube.com/watch?v=OB_HKWKH7NA))

Synopsis: Many trips people take each day are within reasonable biking or walking distance. Investing in cycling infrastructure by cities is necessary to help reduce traffic congestion and pollution, as well as provide an affordable form of transportation and exercise.

- What are some of the benefits of cycling?
- How is a network of bicycling infrastructure, traffic calming measures, and repair shops a crucial component of promoting cycling as mode of transportation?
- In the US, nearly half of all trips are shorter than three miles; how is cycling a better option than adding more infrastructure for cars?
- Could improving networks that empower alternative, sustainable modes of transportation also improve accessibility and equity in different neighborhoods? How can infrastructure changes (e.g., creating new bike lanes) take issues of equity into account?

TRANSPORTATION AND HAPPINESS ([HTTPS://VIMEO.COM/732542898](https://vimeo.com/732542898))

Synopsis: Dr. Yingling Fan, a professor at the University of Minnesota and a research scholar at its Center for Transportation Studies, wants to transform the way we experience transportation. With the help of Minneapolis—St. Paul residents, Dr. Fan has developed an innovative “Transportation Happiness Map” that captures the positive emotions tied to biking, reliable public transportation, safe and scenic paths, and avoiding traffic behind the wheel.

- How is happiness affecting the way people commute and experience transportation?
- How can different community members utilize the “Transportation Happiness Map” to envision, plan, and build a more sustainable transportation ecosystem? Think of some action items for the following members:

- Transportation planners
- Local government officials
- Citizens
- Students

CONCLUDING QUESTIONS

- How do these films convey more sustainable ways of getting around our cities and towns? Do they empower you to think about walking, cycling, or using the bus in new ways?
- Do you think one of these choices would work better for your community than others? Which one and why?
- Could these methods of getting around be used in conjunction with each other? For example, do you think people would bike to a bus station?
- How can policymakers, planners, and citizens ensure that sustainable transportation options reach those who most need it, including traditionally underserved communities?

U.S. infrastructure receiving a C- grade rating.

Lesson 7: How Walkable is your Community¹⁰

DESCRIPTION

This lesson will help students learn about how safe and comfortable it is to walk or bicycle in their community. Students will conduct a simple walkability assessment, using a tool very similar to what professionals use to conduct a similar type of assessment.

LEARNING OUTCOMES

Students will be able to:

- Conduct a simple walkability assessment and evaluate the outcomes
- Describe what conditions make an area more or less walkable
- Identify the benefits of walking
- Identify the factors that impede walking



LESSON TIME

- 1 class period, plus homework
- Optional: 1 class period guest speaker

STANDARDS AND OBJECTIVES

Next Generation Science Standards

- **MS-ESS3-1 Earth and Human Activity.** Connections to Engineering, Technology, and Applications of Science Influence of Science, Engineering, and Technology on Society and the Natural World
 - All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment

California Common Core Standards

- **Writing Standards (Grades 6–12).** Write arguments to support claims with clear reasons and relevant evidence.

8. This lesson is adapted from one developed by the Colorado Department of Transportation's Safe Routes to School program. The original lesson can be found at: <https://www.codot.gov/programs/bikeped/safe-routes/lesson-plans/46SSRWCHowWalkableorBikableisyourCommunity.pdf>. Additional lesson plans related to bicycle and pedestrian skills and lessons are available at: <https://www.codot.gov/programs/bikeped/safe-routes/training-curriculum/srts-lesson-plans.html>.

- **Speaking and Listening Standards (Grades 6–12).** Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on texts, and issues, building on others' ideas and expressing their own clearly.

MATERIALS

- How Walkable Is Your Community? Student Checklist

INSTRUCTIONAL ACTIVITY

First, provide an overview of why being able to walk comfortably and conveniently is important. Engage your students in a brief discussion.

- What are some of the benefits of walking?
 - Improved fitness
 - Cleaner air
 - Reduced risks of certain health problems
 - Greater sense of community (when you get out a walk, you run into neighbors and can develop good relations with your community)
- What factors can make it difficult to walk places?
 - Lack of sidewalks or sidewalk obstructions
 - Busy traffic streets / hard to cross from one side of the street to the other
 - No amenities (e.g. shade, interesting places to walk to)

Students should identify a place to walk. This could be the route to school, a friend's house, or just somewhere fun to go. Each student can pick a different place for their walk. Review the Walkability Checklist with the students and explain how they will complete it after their walk. For example, with each question, there is both a rating scale (1 to 5) as well as details regarding some of the potential problems they may encounter on their way. You can also encourage students to complete the walk with a parent or other adult guardian.

After students complete their walkability assessment, lead a classroom discussion about their experiences. Encourage students not only to describe some of the problems they encountered, but also some ideas for how they could address the problems. Some ideas are presented below (several are actions the students could take in partnership with their parents or other adults).

Checklist Questions	What you can do now	What you and your community can do with more time
1. Did you have room to walk?	<ul style="list-style-type: none"> - Pick another route for now. - Tell your local traffic engineering or public works department about specific problems and provide a copy of the checklist. 	<ul style="list-style-type: none"> - Speak up at community meetings or your local planning commission meeting. - Write or petition your city for improved walkways and gather neighborhood signatures. - Make the media aware of the problem(s). - Work with a local transportation engineer to develop a plan for a safe walking route.
2. Was it easy to cross streets?	<ul style="list-style-type: none"> - Pick another route for now. - Share the problems and checklist with local traffic engineering or the public works department. - Trim your trees or bushes that block the street and ask your neighbors to do the same. - Leave nice notes on problem cars asking owners not to park there. 	<ul style="list-style-type: none"> - Push for crosswalks/ signals/parking changes/ curb ramps at city meetings. - Report to traffic engineer where parked cars are safety hazards. - Report illegally parked cars to the police. - Request that the public works department trim trees or plants. - Make the media aware of the problem(s).
Checklist Questions	What you can do now	What you and your community can do with more time

By 2045, the number of American over age 65 will increase by 77%.
 What does this mean for transportation?

3. Did drivers drive well?	<ul style="list-style-type: none"> - Pick another route for now. - Set an example: ask your parents/adult drivers to slow down and be considerate of others. - Encourage your neighbors to do the same. - Report unsafe driving to the police. 	<ul style="list-style-type: none"> - Petition for more enforcement. - Request protected turns. - Ask city planners and traffic engineers for traffic calming ideas. - Ask schools about getting crossing guards at key locations. - Organize a neighborhood speed watch program.
4. Was is easy to follow safety rules?	<ul style="list-style-type: none"> - Educate yourself about safe walking. - Organize families in your neighborhood to walk together to school. 	<ul style="list-style-type: none"> - Encourage schools to teach walking safety. - Help schools start safe walking programs. - Encourage corporate support for flexible schedules so parents/adults can walk children to school.
5. Was your walk pleasant?	<ul style="list-style-type: none"> - Pick another route for now. - Ask neighbors to keep dogs leashed or fenced. - Report scary dogs to the animal control department. - Report scary people to the police. - Report lighting needs to the police or appropriate public works department. - Take a walk with a trash bag. - Plant trees or flowers in your yard. 	<ul style="list-style-type: none"> - Request increased police enforcement. - Start a crime watch program in your neighborhood. - Organize a community clean-up day. - Sponsor a neighborhood beautification or tree-planting day. - Begin an adopt-a-street program. - Initiate support to provide routes with less traffic to schools in your community.

ADDITIONAL ACTIVITY

After students determine the walkability of their area, they should apply the same concept to the area around the school. A walking tour of the area surrounding the school is encouraged. Students should identify obstacles (e-scooters, debris, crosswalk conditions; visibility of stop, speed limit, or pedestrian crossing signs; street lights, uneven sidewalks, lack of a bike lane, etc.). Students break into groups of 4-5 to develop a campaign that would encourage more of their schoolmates to walk (or bike) to school. Previous examples include apps, poster campaign, social media campaign, videos, competitions, pledges, etc. Additionally, students can brainstorm ways to make their chosen route safer. What would make their path safer? Wider sidewalks, more crosswalks, protected bike lanes, etc. could be included. Students could be asked to design an alternative route with these changes.

Name: _____

*Student Worksheet/Checklist***How Walkable Is Your Community?**

Location of walk: _____

Rating Scale: _____

1. Did you have room to walk?

- ☐ Yes ☐ Some problems:
- ☐ Sidewalks or paths started and stopped
 - ☐ Sidewalks were broken or cracked
 - ☐ Sidewalks were blocked with poles, signs, shrubbery, dumpsters, etc.
 - ☐ No sidewalks, paths, or shoulders
 - ☐ Too much traffic
 - ☐ Something else _____

Rating (circle one)
1 2 3 4 5 6

Locations of problems:

4. How about safety? Could you and your child...

- ☐ Yes ☐ No Cross at crosswalks or where you could see and be seen by drivers?
- ☐ Yes ☐ No Stop and look left, right and then left again before crossing streets?
- ☐ Yes ☐ No Walk on sidewalks or shoulders facing traffic where there were no sidewalks?
- ☐ Yes ☐ No Cross with the light? _____

Rating (circle one)
1 2 3 4 5 6

Locations of problems:

2. Was it easy to cross streets?

- ☐ Yes ☐ Some problems:
- ☐ Road was too wide
 - ☐ Traffic signals made us wait too long or did not give us enough time to cross
 - ☐ Needed striped crosswalks or traffic signals
 - ☐ Parked cars blocked our view of traffic
 - ☐ Trees or plants blocked our view of traffic
 - ☐ Needed curb ramps or ramps needed repair
 - ☐ Something else _____

Rating (circle one)
1 2 3 4 5 6

Locations of problems:

5. Was your walk pleasant?

- ☐ Yes ☐ Some problems:
- ☐ Needed more grass, flowers, or trees
 - ☐ Scary dogs
 - ☐ Scary people
 - ☐ Not well lighted
 - ☐ Dirty, lots of litter or trash
 - ☐ Dirty air due to automobile exhaust
 - ☐ Something else _____

Rating (circle one)
1 2 3 4 5 6

Locations of problems:

3. Did drivers behave well?

- ☐ Yes ☐ Some problems: Drivers...
- ☐ Backed out of the driveways without looking
 - ☐ Did not yield to people crossing the street
 - ☐ Turned into people crossing the street
 - ☐ Drove too fast
 - ☐ Sped up to make it through traffic lights or drove through traffic lights?
 - ☐ Something else _____

Rating (circle one)
1 2 3 4 5 6

Locations of problems:

How does your neighborhood stack up?

Add up your ratings and decide

- | | | |
|--------------|--------------|---|
| 1. _____ | 26-30 | Celebrate! You have a great neighborhood for walking. |
| 2. _____ | 21-25 | Celebrate a little. Your neighborhood is pretty good. |
| 3. _____ | 16-20 | Okay, but it needs work. |
| 4. _____ | 11-15 | It needs lots of work. You deserve better than that. |
| 5. _____ | 5-10 | It's a disaster for walking! |
| Total: _____ | | |

LESSON 8: TRANSPORTATION JOBS AND PROFESSIONS

DESCRIPTION

This lesson will help students learn about careers and professions in transportation.

LEARNING OUTCOMES

Students will be able to:

- Identify transportation careers by their work tasks, educational requirements, rewards, challenges, and drawbacks
- Explore the differences between vocational, 2-year, and 4-year institutions



LESSON TIME

- One class period with homework (and potential next day presentation)

STANDARDS AND OBJECTIVES

California Common Core Standards

- **Reading Standards for Informational Text (Grades 6-12)**
 - Cite the textual evidence that most strongly supports an analysis of what the text says explicitly as well as inferences drawn from the text.
 - Determine a central idea of a text and analyze its development over the course of the text, including its relationship to supporting ideas; provide an objective summary of the text.
 - Use technology, including the Internet, to produce and publish writing and link to and cite sources as well as to interact and collaborate with others, including linking to and citing sources.
 - Conduct short research projects to answer a question, drawing on several sources and generating additional related, focused questions for further research and investigation.

MATERIALS

- Career Flowchart Handout
- Writing implement

INSTRUCTIONAL ACTIVITY

Begin class with a discussion that contributes to student understanding of transportation career possibilities.

Ask students: What is a career? (Definition: An occupation or profession requiring special transportation. It often becomes a person's life's work.)

Ask students: What are your parents' careers? How does transportation touch that career? Avoid the obvious commuting, i.e. nurse- supplies that have to be delivered regularly, hospital emergencies are helicoptered in/ out, EMT arrivals, etc.)

Direct students to the Career Flowchart. Have them look over the different colleges, majors, and careers. Let them know there are overlapping majors and careers; thus showing the naturalness of multidisciplinary fields in the real world.

1. Have them circle 2-4 majors and careers that pique their interest from the corresponding boxes.
2. Have them fill in the "Possible Employers" row (ex. Amazon, airport, FDA, Transit agency, Google, etc.)
3. Have students select one of the careers that most interests them and identify some pros and cons to making that their career. This becomes part of their homework as they explore a career of their choice and prepare a career day style presentation for the class.
 - a. The presentation can include a ppt. and them "dressing up" to convey their career choice.
 - b. The following websites can provide a good resource for them:
 - http://learningpath.org/article_directory/sh/page/Distribution,%20Transportation,%20and%20Materials%20Moving/sh/Job_Titles_and_Careers_List.html
 - <http://www.owlguru.com/career/list/transportation/>

Women accounted for less than 15% of the total transportation workforce in 2017.

CAREER FLOWCHART HANDOUT

MINETA UNIVERSITY

COLLEGES	APPLIED SCIENCES AND ART COLLEGES	BUSINESS COLLEGE	EDUCATION COLLEGE	ENGINEERING COLLEGE	ARTS AND LETTERS COLLEGE	SCIENCE COLLEGE	SOCIAL SCIENCES COLLEGE
CAREER EXAMPLES (Feel free to add some of your own)	<div>⋮</div> Aircraft Designer Inspection Officer Aerospace Technician Drone/ Payload Specialist Public Relations/ Communications Law Enforcement <div>⋮</div>	<div>⋮</div> Human Resources Finance Team Labor Relations <div>⋮</div>	<div>⋮</div> Corporate Trainer <div>⋮</div>	<div>⋮</div> Pilot and crew Energy manager Production manager Chemical quality control Water Treatment Auto mechanic <div>⋮</div>	<div>⋮</div> Translator Public relations/ media contact Communications Advertising Copywriter <div>⋮</div>	<div>⋮</div> Environmental Technician Health & Safety Specialist Nurse EMT Research Assistant Agricultural Technician <div>⋮</div>	<div>⋮</div> Law City Planner Transportation Planner Environmental Lobbyist Law Enforcement <div>⋮</div>
POSSIBLE EMPLOYERS (Can you think of some possible employers to add?)							

MINETA UNIVERSITY

COLLEGES	APPLIED SCIENCES AND ART COLLEGES	BUSINESS COLLEGE	EDUCATION COLLEGE	ENGINEERING COLLEGE	ARTS AND LETTERS COLLEGE	SCIENCE COLLEGE	SOCIAL SCIENCES COLLEGE
MAJORS	Aerospace	Accounting/ Finance	Child and Adolescent Development	Aviation & Tech	Art	Biological Science	Cultural Studies
	Health/ Nursing	Management Information Systems	Counselor Education	Chemical and Materials Eng.	Dance	Chemistry	Communications
	Hospitality/ Recreation	Marketing/ Business	Education Leadership	Civil and Environmental Eng.	Design	Computer Science	Economics
	Journalism and Communications	Organization/ Management	Elementary Ed.	Computer Eng.	English	Geology	Environmental Studies
	Social Work		Secondary Ed.	Electrical Eng.	Languages	Mathematics	Geography
				Industrial Eng.	Music	Meteorology	History
				Mechanical and Aerospace Eng.	Philosophy	Marine Biology	Political Science
					Radio, TV, Film	Physics	Sociology
					Animation/ Illustration	Astronomy	Urban Studies

CAREER FLOWCHART HANDOUT

MINETA UNIVERSITY

COLLEGES

APPLIED
SCIENCES AND
ART COLLEGES

BUSINESS
COLLEGE

EDUCATION
COLLEGE

ENGINEERING
COLLEGE

ARTS AND
LETTERS
COLLEGE

SCIENCE
COLLEGE

SOCIAL
SCIENCES
COLLEGE

PERSONAL
PROS &
CONS

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CAREER FLOWCHART HANDOUT

APPRENTICESHIPS

TRANSPORTATION SUBSECTORS

RELATED APPRENTICESHIP PROGRAMS

HIGH-DEMAND APPRENTICESHIP OCCUPATIONS

POSSIBLE EMPLOYERS

(Can you think of some possible employers to add?)

TRUCKING	TRANSIT	AIR	HIGHWAY CONSTRUCTION	RAIL	MARITIME
Heavy Truck Driving/ Light Truck Driving/ Truck Mechanics/ Industrial Tractor Operators/ Transportation Technician	Bus Drivers / Bus Mechanics / Transportation Technician / Bus Fleet Sustainability Mechanic / Light Rail Technician / Light Rail Operator / Building Operation Engineer / Light	Aircraft Mechanics and Service Technicians / Assembly Technicians /	Pipelay / Maintenance Worker / General Construction / Ironworker / Cement Mason / Welder / Laborer / Landscaping / Machinist / Bricklayer	Rail Car Repair Technician / Passenger Rail Mechanic / Electrician / Lineman	Motorboat Mechanic / Service Technician / Tankerman / Ferry Operator / Sheet Metal Worker / Steelworker / Water Transportation Worker
Diesel Mechanic / Truck Driver / Distribution Manager	Bus Driver / Vehicle Mechanic	Avionics Technician	Construction Laborer / Equipment Operator	Rail Car Technician	Shoreside Tankerman / Ferry Operator
Truck Driving Companies / State Governments / Businesses	Schools / City Transit Agencies	Airports	Businesses / Local Governments	City and State Transit Agencies	Logistics Businesses / WA State Ferries /

CAREER FLOWCHART HANDOUT

APPRENTICESHIPS

TRANSPORTATION
SUBSECTORS

PERSONAL PROS
& CONS

TRUCKING	TRANSIT	AIR	HIGHWAY CONSTRUCTION	RAIL	MARITIME

Lesson 9: Understanding Sustainable Transportation

DESCRIPTION

In this lesson, students will be introduced to the definition of sustainable transportation. They will think critically about the main choices, benefits, and costs associated with sustainable transportation.

LEARNING OUTCOMES

Students will be able to:

- Analyze, compare, and contrast the various options and characteristics of sustainable transportation
- Understand the definition of sustainable transportation



LESSON TIME

- One class period

STANDARDS AND OBJECTIVES

Next Generation Science Standards

- **MS-ESS3-1 Earth and Human Activity.** Connections to Engineering, Technology, and Applications of Science Influence of Science, Engineering, and Technology on Society and the Natural World
 - All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment

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 - Use technology, including the Internet, to produce and publish writing and link to and cite sources as well as to interact and collaborate with others, including linking to and citing sources.
 - Conduct short research projects to answer a question, drawing on several sources and generating additional related, focused questions for further research and investigation.

MATERIALS

- Understanding Sustainable Transportation Student Worksheet

INSTRUCTIONAL ACTIVITY

Students should complete the two tables on the “Understanding Sustainable Transportation Student Worksheet.” Sample tables have been completed and are shown below. Answer can vary, but the intent is that students are able to explain their responses within the context of sustainable transportation. Encourage students to think creatively and critically. For the table on assessing sustainable transportation options, ask students to specify both a mode and energy source and to think beyond systems they may be familiar with. Encourage them to think of new transportation configurations.

CHARACTERISTICS OF SUSTAINABLE TRANSPORTATION

Complete the table below to identify and explain six desirable characteristics of sustainable transportation.

Characteristic	Why is it desirable?
1. Fast	So people will want to use it and it can be used for many purposes, such as emergencies or going to school or work.
2. Convenient	So people will be able to go when and where they want. Mass transit should be convenient to homes and businesses so people can get to where they want to go without having to walk long distances.
3. Efficient	So it doesn't use too much fuel, or maybe uses renewable fuel sources. This could also mean that the system is faster than driving a car in traffic.
4. Non-polluting and cares for the Earth	So we can have clean air to breathe and don't leave future generations with pollution, messy clean-ups, or disposal problems.
5. Fair/affordable	So people who need transportation will have access to it, and many people can afford to get where they need to go.

There will be 460,000 transportation jobs available per year through 2022.

6. Safe for people and animals	So people and employees don't get hurt using or working around the system or the fuel required to operate it. If it is a mass transit or high-speed system, it must have fences or barriers so animals and people don't get hurt or killed by the system.
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ASSESSING SUSTAINABLE TRANSPORTATION OPTIONS

List four sustainable transportation modes and several positive and negative attributes for each.

Mode	Positive Attributes	Negative Attributes
1. Mass transit underground system that runs only on renewable energy	Non-polluting fuel source; many people can ride; limited interaction with animals and people (non-riders) to limit accidents	Transit isn't typically as fast or convenient as private automobile; expensive to dig the tunnels; doesn't provide emergency transportation
2. Mass transit system that runs on a combination of renewable energy and fossil fuels	Technology already exists; many people can ride; could be less expensive to build than other systems; running on both renewable and fossil fuels reduces dependence on fossil fuels and can reduce pollution	Transit isn't typically as fast or convenient as private automobile; still relies on fossil fuel; doesn't provide emergency transportation
3. Commuter airplanes	Fast; no traffic jams; technology already exists	Very expensive; use a lot of fossil fuel; limited number of airports (and many aren't big enough to support this)
4. Express electric overhead tram system	Depending on source of electricity, could be non-polluting; doesn't contribute to traffic jams; many people could ride	Expensive to build; could be visually unattractive with overhead systems all over the place

Connected vehicles with crash avoidance technology could address 80% of crashes involving unimpaired drivers.

UNDERSTANDING SUSTAINABLE TRANSPORTATION STUDENT WORKSHEET

By now you already know a lot about transportation. If somebody asked you what sustainable transportation was, you'd probably have quite a bit to say. You could tell them about the different fuels available and explain the various social, economic, and environmental costs associated with them. You could also talk about why transportation must be convenient and fast so people will use it. You could explain benefits and drawbacks of mass transportation. How much the transportation costs and whether it can be made available to all are other issues that you might discuss with someone who asked you about transportation.

But if someone asked you for a definition of sustainable transportation, you might have a bit of trouble. People who work on many issues related to sustainability have developed the following definition: "meeting the needs of the present without compromising the ability of future generations to meet their own needs."

When you think about it, this definition includes many possibilities related to transportation. What might those be? Sustainable transportation can include using mass transit, like buses, trains, light rail, and carpools. It could also be about using fuel efficiently. It can be about how employers address transportation issues by allowing employees to telecommute, have staggered shifts, or work longer hours so they don't have to make so many trips to work or drive during rush hours. All of these concepts, and many others, are part of sustainable transportation.

CHARACTERISTICS OF SUSTAINABLE TRANSPORTATION

Complete the table below to identify and explain six desirable characteristics of sustainable transportation.

Characteristic	Why is it desirable?

ASSESSING SUSTAINABLE TRANSPORTATION OPTIONS

List four sustainable transportation modes and several positive and negative attributes of each.

Mode	Positive Attributes	Negative Attributes