G6–8

LESSON 6 — A Problem of Design

MODULE OVERVIEW

Module Title: **Designing a Vehicle for the Year 2020**

Module Description: Students learn about natural resources, human effect on the environment and engineering design through this brief module on vehicle transportation. They study how vehicles of today are designed and how vehicles could be improved for the future. Using real world scientific data and science reasoning skills, they investigate existing energy sources and designs for vehicles as well as emerging alternative energy sources and designs for vehicles. They take a realistic look at existing energy and fuel infrastructure and consider how that infrastructure will change, or need to change, by 2020. Students conduct investigations into vehicle design, and use content from videos and online resources. Finally, they apply this knowledge to realistically design their own "vehicles of the future" and to create multimedia presentations of their ideas for classmates.

Module Project: Students consider how fuel-efficient and environmentally friendly technologies will impact the kinds of vehicles available in the year 2020. They use videos, multimedia presentations, or pamphlets to design and advertise their "cars of the future."

LESSON OVERVIEW

Lesson Time: 45–90 minutes

Over the past few lessons, students have investigated a variety of alternative energy sources that might eventually replace gasoline as the primary fuel for U.S. vehicles. For now, however, the most cost-effective option for fuel-conscious drivers might be a compromise between alternative energy and gasoline: the hybrid gas-electric vehicle. In Lesson 6, students will learn more about the hybrid technology powering some contemporary vehicles. They will close by investigating a variety of future technologies to keep an eye on as the year 2020 approaches.

BACKGROUND FOR TEACHERS

Hybrid electric vehicles (HEVs) combine the internal combustion engine of a conventional vehicle with the high-voltage battery and electric motor of an electric vehicle. As a result, HEVs can achieve twice the fuel economy of conventional vehicles and have several other advantages as well. These include:

- Greater operating efficiency because HEVs use regenerative braking, in which the energy from the wheels turns a motor, which functions as a generator to convert energy normally wasted during coasting and braking into electricity, which is then stored in a battery until needed by the electric motor;
- Lighter engines because HEV engines can be sized to accommodate average load, not peak load, which reduces the engine's weight;
- Greater fuel efficiency because hybrids consume significantly less fuel than vehicles powered by gasoline alone;
- Cleaner operation because HEVs can run on alternative fuels (which have lower emissions), thereby decreasing our dependency on fossil fuels (which helps ensure our national security); and
- Lighter vehicle weight overall because special lightweight materials are used in their production.

Essentially, an HEV combines an energy storage system, a power unit, and a vehicle propulsion system. The primary options for energy storage include batteries, ultracapacitors (which have the potential to be more powerful and longer lasting than batteries), and flywheels (motorized spinning wheels that store kinetic energy). Although batteries are by far the most common choice for energy storage, research is still being done in other energy storage areas.

Hybrid power unit options include spark ignition engines (which use electricity to ignite the fuel mixture), compression ignition engines (which generate heat by rapidly compressing air), and fuel cells (also known as hydrogen cells, which convert the chemical energy of hydrogen and oxygen ions into electricity and produce water as a by-product rather than emissions). Propulsion in hybrids can come entirely from an electric motor or from a combination of an electric motor and a traditional internal combustion engine.

Plug-in hybrid electric vehicles (PHEVs) are similar to HEVs in that both combine electric motors and internal combustion engines. However, a PHEV can operate solely on electricity by plugging into the power grid, bypassing the engine entirely.

Source:
U.S. Department of Energy: Hybrid Electric Vehicles (HEVs); How Hybrids Work

Teacher Preparation: As a reminder: throughout the module, students should check in with fellow design team members (teams of 3-4 identified at the end of Lesson 1). In addition, each student should continue to take individual notes in his or her Engineering Notebook that might apply to the final team idea. You may wish to meet with students at different points throughout the module to check on their progress and remind them of the final project.

By this point, each team should have produced several sketches and diagrams of its design.

LESSON OBJECTIVES

By the end of this lesson, students should be able to:

- Investigate hybrid electric vehicle technology.
- Compare and contrast hybrid electric vehicles with non-hybrid vehicles.
- Explore additional technologies for improving a vehicle's fuel efficiency and eco-friendliness.
- Finalize their vehicle designs for the year 2020.

Please see *Standards Addressed in G6-8* for a list of the applicable science, technology, engineering and math standards, as well as the 21st Century Skills.

Lesson Essential Questions:

1. How do hybrid electric vehicles work?
2. How are hybrid electric vehicles similar to and different from non–hybrid electric vehicles?
3. What other technologies exist for improving a vehicle's fuel efficiency and eco-friendliness?
4. What kinds of fuel-efficient, eco-friendly vehicles will exist in the year 2020?

Key Vocabulary (appropriate for a word wall):

hybrid electric vehicle (HEV), *regenerative braking*, *idling*, *fuel cell*, *battery*, *ultracapacitor*

RESOURCES

Materials needed:

- Chalkboard and chalk, or whiteboard (or interactive whiteboard, if available)
- Computer with Internet access linked to a projector or TV (for whole class to view at once), PLUS additional computers with Internet access (one per student or student pair)
- Chart paper or poster board (one for each team of students)
- Mounting tape
- Engineering Notebook for each student

Resources from FuelOurFutureNow.com:

- Video: *Green Gadgets: ZAP!® Truck* (3:49)

Resources from other Web sites:

- http://www.fueleconomy.gov/feg/hybridAnimation/swfs/hybridframe.html – *How Hybrids Work* (Flash animation or HTML version)
- http://www.afdc.energy.gov/afdc/hev_calculator/single.php – *HEV Cost Calculator Tool* (Single Car Comparison)
- http://www.fueleconomy.gov/feg/mostEfficient.shtml – Video: *2007 SAE Super Mileage Competition* (2:30)
- http://www.afdc.energy.gov/afdc/ – *Alternative Fuels & Advanced Vehicles Data Center*

- http://www.afdc.energy.gov/afdc/fuels/emerging.html – *Emerging Fuels*
- http://www.afdc.energy.gov/afdc/vehicles/idle_reduction.html – *Idle Reduction*
- http://www.afdc.energy.gov/afdc/vehicles/fuel_cell.html – *Fuel Cells*
- http://www.afdc.energy.gov/afdc/vehicles/fuel_economy_tires_light.html – *Low Rolling Resistance Tires*
- http://www1.eere.energy.gov/vehiclesandfuels/technologies/energy_storage/index.html – *Batteries and Ultracapacitors*

Student Worksheets Required:

- *How Hybrids Work* (one per student)
- *Comparing Hybrids* (one per student)
- *Additional Technologies* (one per student)

What skills do students need for this lesson?

- Use the Internet safely and appropriately to search for specific data
- Compare and contrast various technologies
- Communicate information to peers

TEACH

Engage

- Review the previous few lessons by having students list as many ways as they can think of to improve a vehicle's fuel efficiency and eco-friendliness. Group students' responses on the board by category: Alternative Energy Sources, Emissions Controls, Lightweight Materials, and Other. Explain to students that in this lesson, they will focus on filling out the "Other" category.
- Show students the video on the *ZAP! Truck* (from *Green Gadgets*). Show the video to the entire class. As students watch, have them note ways that a *hybrid electric vehicle (HEV)*, such as the truck featured in this video, differs from an electric vehicle, such as the ones studied in Lesson 2.
- Discuss students' responses to the video. Explain that any vehicle that gets its power from multiple energy sources, one of which is an electric motor, is a hybrid electric vehicle. The truck in the video combines its electric motor with solar power, which is completely clean and renewable. However, most hybrid electric vehicles in the United States combine electric motors with traditional gasoline-powered engines. Thus, though they are cleaner and more sustainable than entirely gasoline-powered vehicles, they are still at least partly dependent on nonrenewable fossil fuels.

Explore

- Distribute the *How Hybrids Work* worksheet to students. Have students investigate the technology that powers hybrid vehicles by interacting with the corresponding *How Hybrids Work* Flash activity on the FuelEconomy.gov Web site. Explain that the worksheet refers

primarily to the "Hybrid" tab, not the "Full Hybrid" or the "Stop/Start" tabs, though students should investigate all three vehicle types. To help students better understand hybrid technology, encourage students to reproduce each diagram in the activity in their Engineering Notebooks.

- Distribute the *Comparing Hybrids* worksheet to students. Have students use the HEV Cost Calculator Tool at AFDC.energy.gov to compare the average annual costs of popular hybrid electric vehicles and their non-hybrid counterparts. Emphasize that the data produced by the Cost Calculator represents typical estimates and should not be assumed to apply to every single vehicle of a particular make and model. Students should consider benefits to the environment when thinking about the reasons people might purchase hybrids over non-hybrids even when the total cost of the hybrid is greater.

NOTE: If this lesson requires two class periods, this is a good place to break. Remember to end the first part of the lesson with a quick review of what students have done so far. Try to give each team a chance to meet briefly at the end of the period to discuss its findings. Remember to begin the second part of the lesson with a brief review of what students learned in the previous period.

Explain

- Have students gather in their teams to briefly discuss their findings. Each team should produce a graphic organizer comparing and contrasting hybrid electric vehicles, traditional gasoline-powered vehicles, and vehicles powered by alternative energy sources. Students may work in their Engineering Notebooks. Possible graphic organizers include Venn diagrams or T-charts. Students should consider the advantages and disadvantages of each kind of vehicle with regard to cost, fuel efficiency, convenience (for example, how simple it is to refuel), and effect on the environment.
- Once teams have produced rough drafts of their graphic organizers for you to check, they should transfer their drafts to a large piece of chart paper or poster board to post around the classroom. When all graphic organizers have been posted, teams should travel around the room, from organizer to organizer, for a gallery walk. Each team should note at least one new idea or contrasting point made by each other team.
- Regroup as a class to discuss what each team created and noted from the gallery walk. Have each team give a brief update to the rest of the class on its progress toward the final project—specifically, what alternative energy sources are team members considering using in their vehicle designs, and why are they leaning toward those particular sources?

Extend

- Show students the video about the 2007 SAE Supermileage Competition from FuelEconomy.gov. Show the video to the entire class. Afterward, emphasize that competitions such as this one bring the challenge of designing a more fuel-efficient, eco-friendly vehicle to many people, not only professional scientists and engineers, and that every person will have a different perspective on which technologies offer the most promise.

- Note that the Progressive Automotive X PRIZE competition is very similar, with teams comprised of inventors, designers, members of the automotive industry, engineers, scientists and even students. (See ProgressiveAutoXPRIZE.org for more information.)
- Explain that in addition to the various technologies that students have explored over the past few lessons, there are other technologies that are still being developed. Students will now have an opportunity to explore some of these other technologies and possibly incorporate them into their vehicle designs for the year 2020.
- Distribute the *Additional Technologies* worksheet. Teams should assign each member at least one of the additional technologies to research on the AFDC.Energy.gov Web site:
    - Emerging Fuels
    - Idle Reduction
    - Fuel Cells
    - Low Rolling Resistance Tires
    - Batteries and Ultracapacitors
- Bring team members back together to perform a jigsaw activity. In this activity, each team member teaches his or her additional technologies to the rest of the team, so that by the end of the activity every student's worksheet is completely filled in.
- Have each team present to the rest of the class one interesting fact they learned about an additional technology.

Evaluate

- Have students enter their findings from this activity in their Engineering Notebooks. In particular, students should include plans for incorporating what they have learned about additional technologies into their final vehicle designs.
- Students should meet in their teams to finalize their plans for their vehicles for the year 2020. Give teams some time to review the materials related to their designs in their Engineering Notebooks—by this point, each team should have produced several sketches and diagrams of its design. Each team must decide on the following to incorporate into its vehicle:
    - An alternative energy source or a combination of alternative energy sources
    - A plan to create new infrastructure or improve existing infrastructure so that its vehicle can be conveniently refueled throughout the United States
    - A strategy to reduce the weight of its vehicle
    - A strategy to decrease the air pollution caused by its vehicle's emissions
    - At least one additional technology that will either improve its vehicle's fuel efficiency or lessen the negative impact its vehicle has on the environment

Wrap-Up

- Have students recall what they did in Lesson 6. Return to the categorized list from the beginning of the lesson. Have students identify and describe additional items to add to the "Other" category.

- Briefly review the topics that students have covered thus far: *fuel efficiency*, *alternative energy sources*, *vehicle weight reduction*, *vehicle emissions*, *transportation infrastructure*, and *hybrid electric vehicles*.
- Preview Lesson 7. Explain that they have now explored many technologies for improving a vehicle's fuel efficiency and helping it make a more positive impact on the environment. By now students should have a good idea about how each of these technologies might or might not be appropriate for their vehicle designs for the year 2020. The last step is for students to work in their teams to create advertisements for their vehicles, and then they will present these advertisements to the rest of the class.

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How Hybrids Work

Watch the Flash animation (http://www.fueleconomy.gov/feg/hybridAnimation/swfs/hybridframe.html) to discover how the parts of a typical hybrid electric vehicle work together during each stage of the driving process. Then, answer the question below on the back of this sheet.

	Battery	Electric Motor	Gasoline Engine
General Overview			
Starting			
Cruising			
Passing			
Braking			
Stopped			

What are the key differences between a hybrid vehicle and a "full" or "stop/start" hybrid vehicle?

Comparing Hybrids

Use the Cost Calculator Tool (http://www.afdc.energy.gov/afdc/hev_calculator/single.php) from the U.S. Department of Energy to see how each of the five top-selling HEVs from 2008 compare to their non-hybrid counterparts. Then, answer the question below on the back of this sheet.

	Purchase Price	Resale Value	Annual Maintenance	Annual Fuel	Total Cumulative
1. Toyota Prius® (Hybrid)					
Toyota Yaris® (Standard)					
2. Toyota Camry® (Hybrid)					
Toyota Camry® (Standard)					
3. Honda Civic® (Hybrid)					
Honda Civic® (Standard)					
4. Toyota Highlander® (Hybrid)					
Toyota Highlander® (Standard)					
5. Ford Escape® (Hybrid)					
Ford Escape® (Standard)					

For most of these vehicles, the total cumulative cost of the hybrid is greater than the total cumulative cost of the non-hybrid. What benefits do the hybrids offer that might outweigh their greater cost?

Additional Technologies

Explore the Alternative Fuels & Advanced Vehicles Data Center (http://www.afdc.energy.gov/afdc/) to learn about the following developing technologies.

Technology	Description	Examples	Benefits	Challenges
Emerging Fuels				
Idle Reduction				
Fuel Cells				
Low Rolling Resistance Tires				
Batteries and Ultra-capacitors				