

Drivetrain Lab Teacher Guide: AP Environmental Science

By Chris James, Oddly Audacious Apps · oddlyaudaciousapps.com/drivetrain · October 2026

At a glance

Students use a free online lab to answer one question: **under what conditions does an electric car emit less over its life than a gas car?** They split each car’s emissions into manufacturing, fuel production and combustion, check the tool’s numbers by hand, then change one variable at a time.

Course	AP Environmental Science (grades 10–12)
Time	45–55 minutes, an 80–90 minute block, or two class periods
Grouping	Pairs
Devices	One laptop, Chromebook or tablet per pair; phones work in a pinch
Materials	Drivetrain Lab: Classroom Edition (free, no login), the lab sheet in this guide, calculators optional
Prior knowledge	Fossil fuels and electricity generation; greenhouse gases; unit conversions
Product	Lab sheet + one four-part FRQ

The tool. Drivetrain Lab: Classroom Edition opens with four compact SUVs: a Tesla Model Y (electric), Toyota RAV4 Plug-in Hybrid, Toyota RAV4 Hybrid and Honda CR-V (gas). Same size class means size isn’t a confounding variable. Students can swap in other cars, any U.S. state, a mileage and a climate. The page saves settings in each student’s browser; **Reset to the starting example** restores the reference setup used in the answer key.

Reference settings (the tool’s starting example): Arizona, 12,000 miles per year, hot summers, 55% town driving. Keep these for the class-wide work so answers match the key, then let students try their own state in Part C.

Course connections and objectives

The lesson fits best late in Unit 6 or as a bridge into Unit 9.

Framework	Connection
AP Environmental Science	Unit 6 Energy Resources and Consumption (fossil fuels, electricity generation, 6.13 Energy Conservation); Unit 7 Atmospheric Pollution (7.2 Photochemical Smog); Unit 9 Global Change (9.4 Increases in the Greenhouse Gases)
AP science practices	4 Data Analysis; 6 Mathematical Routines; 7 Argumentation
NGSS	HS-ESS3-4 (evaluate a technological solution that reduces human impacts); HS-ESS3-6 (computational representation of human modification of Earth systems); HS-ETS1-3 (evaluate solutions using criteria and trade-offs)

Students will be able to:

1. Partition a vehicle’s lifecycle emissions into manufacturing, fuel production and combustion.
2. Use dimensional analysis to calculate yearly CO₂ from fuel or electricity use.
3. Explain how a state’s electricity mix changes an electric car’s emissions.
4. Calculate and interpret a carbon payback distance.
5. Distinguish greenhouse gases from criteria pollutants, and connect where pollution is released to environmental justice.

Choose your schedule

Pick the column that matches your class length; minutes for each part are listed, and a dash means that part moves to homework or is skipped.

Part	Short period (45-55 min)	Block (80-90 min)	Two days (2 × 45-55 min)
Warm-up	5	8	Day 1: 5
Launch	5	7	Day 1: 10
A. Baseline	12	15	Day 1: 15
B. Do the math	12	15	Day 1: 20
C. Change one variable	10 (grid tests only)	15	Day 2: 15
E. Your own state (extension)	—	—	Day 2: 15
D. FRQ practice	Homework	12	Day 2: 12
Debrief and exit	6	8	Day 2: 8
Total	50	80	50 + 50

Shorter still (30-40 minutes): run the Launch, Part A and the West Virginia and Washington rows of Part C, then use the FRQ as homework.

Block over 90 minutes: add Part E, or the cost extension in the teaching notes.

Lesson sequence

Each part below matches a row in the schedule table and a section of the lab sheet.

Warm-up. Quick-write: “An electric car has no tailpipe. Does it have zero emissions?” Pairs share. Collect three or four ideas on the board; students usually name the battery, mining and the power plant.

Launch. Project the lab. Walk through Question 1 with the four starting cars. Name the three bar segments (building the car, producing and delivering fuel, burning fuel at the tailpipe or power plant) and the unit, grams of CO₂-equivalent per mile. Point out the Reset button.

A. Baseline. Pairs copy the reference values for all four cars into the Part A table and answer A1-A3. Circulate and ask: “Which segment is biggest for each car, and why?”

B. Do the math. With the tool closed or face down, pairs calculate the gas SUV’s tailpipe CO₂ and the EV’s power-plant CO₂ for a year, then compare with the tool’s “CO₂ per year from driving only” row. The gap (the tool’s numbers are higher) is the fuel-production segment, which makes a good probing question.

C. Change one variable. Pairs reset before each test and change only one setting: West Virginia, Washington, 5,000 miles, 25,000 miles, then cold winters. They record the results and explain each change. In a short period, assign only the two state tests.

D. FRQ practice. Students work alone on the four-part FRQ, then self-score or trade with a partner using the scoring guide.

E. Your own state (extension). Pairs set the tool to your state and find the electric car’s payback distance. They then look up your state’s electricity mix (the EIA state profiles work well) and write two sentences linking the mix to the result.

Debrief and exit. Discuss three prompts:

- Why is the plug-in hybrid in West Virginia slightly worse than the gas car?
- Who breathes the air near a tailpipe, and who breathes the air near a power plant?
- Which drivetrain would you recommend for your own community, and under what conditions?

Exit ticket: one sentence answering the driving question, with a number from the lab.

FRQ practice

This four-part item is written in the style of an AP calculation question and is worth 4 points.

A commuter in Arizona drives 12,000 miles per year. A gas SUV gets 30 miles per gallon. Burning one gallon of gasoline releases about 9 kg of CO₂.

- a. Calculate the CO₂ the gas SUV releases from its tailpipe in one year. Show your work.
- b. An electric SUV of the same size uses 0.26 kWh per mile. Arizona’s grid emits about 0.33 kg CO₂ per kWh delivered. Calculate the electric SUV’s yearly CO₂ from electricity. Show your work.
- c. Building the electric SUV releases about 2,300 kg more CO₂ than building the gas SUV. Using your answers from (a) and (b), calculate how many years it takes the electric SUV to make up this difference.
- d. Identify one change to the electric grid that would shorten this payback time and explain why.

Scoring guide (1 point each)

Part	Earns the point
(a)	12,000 mi ÷ 30 mi/gal = 400 gal; 400 gal × 9 kg/gal = 3,600 kg CO ₂ , with setup and units shown
(b)	12,000 mi × 0.26 kWh/mi = 3,120 kWh; 3,120 kWh × 0.33 kg/kWh ≈ 1,030 kg CO ₂ (accept 1,000–1,040)
(c)	Yearly savings = 3,600 – 1,030 ≈ 2,570 kg; 2,300 ÷ 2,570 ≈ 0.9 years (accept 0.8–1.0, or a value consistent with the student’s own (a) and (b))
(d)	Names a lower-carbon source replacing coal or natural gas (solar, wind, hydro, nuclear, geothermal) and explains that each kWh then emits less, so the electric SUV saves more per mile and repays sooner

To adapt for your state: replace 0.33 kg/kWh in part (b) with your state’s figure. The tool’s Question 4 shows the electric car’s result for every state, and EPA eGRID publishes the underlying rates.

Student lab sheet: Is the EV always cleaner?

Copy this section into its own document for students. Cross out any part your schedule skips.

Name: _____ Partner: _____ Class: _____

Part A: Baseline. Press Reset to the starting example. Fill in from Questions 1 and 2 of the lab.

Car	Building (g/mi)	Fuel production (g/mi)	Burning (g/mi)	Lifecycle (g/mi)	t CO ₂ e per year	Smog rating
Tesla Model Y (EV)						
RAV4 Plug-in Hybrid						
RAV4 Hybrid						
Honda CR-V (gas)						

- A1. Which car has the largest “building” emissions? What part of that car explains it?
- A2. For the EV, where does the “burning” happen? Name two fuels that might be burned there.
- A3. Calculate the percent reduction in lifecycle CO₂ from the CR-V to the Model Y.

Part B: Do the math (tool closed). Show units at every step.

- B1. The CR-V burns 411 gallons per year. Each gallon releases 8,887 g CO₂ at the tailpipe. Find its tailpipe CO₂ per year in metric tons.
- B2. The Model Y uses 3,147 kWh per year. The Arizona grid emits 326 g CO₂ per kWh delivered. Find the power-plant CO₂ per year in metric tons.

- B3. Compare B1 and B2 with the tool's "CO₂ per year from driving only" row. Why are the tool's numbers a little higher?

Part C: Change one variable. Reset before each test, then change only the setting named.

Test	Model Y lifecycle (g/mi)	CR-V lifecycle (g/mi)	EV payback (miles)	What changed and why
State: West Virginia				
State: Washington				
5,000 miles per year				
25,000 miles per year				
Climate: cold winters				

- C1. In West Virginia, compare the RAV4 Plug-in Hybrid with the CR-V. Explain the result.
- C2. Why does mileage change the payback time in years but not in miles?
- C3. Use Question 4. In how many states does the Model Y beat the CR-V? Which state's grid is cleanest, and why might that be?

Part D: FRQ. Answer the four-part FRQ your teacher provides.

Part E: Your own state (if assigned).

- E1. Our state: _____ Model Y lifecycle: _____ g/mi CR-V lifecycle: _____ g/mi Payback: _____ miles
- E2. Our state's largest sources of electricity are _____.
- E3. Explain how E2 accounts for E1 in two sentences.

Exit ticket. Under what conditions does an electric car emit less than a gas car over its life? Use one number from today's lab.

Answer key

Values come from the lab at the reference settings (Arizona, 12,000 mi/yr, hot summers, 55% town); answers within a few g/mi are correct, since rounding varies.

Part A

Car	Building	Fuel production	Burning	Lifecycle (g/mi)	t CO ₂ e/yr	Smog rating
Tesla Model Y (EV)	49	9	86	143	1.7	10
RAV4 Plug-in Hybrid	45	15	129	190	2.3	not rated
RAV4 Hybrid	40	43	210	293	3.5	7
Honda CR-V (gas)	38	62	305	405	4.9	6.5

- A1. The Model Y: its 62 kWh battery adds about 4 t of CO₂ to manufacturing, partly offset by having no engine or transmission.
- A2. At power plants; in Arizona mainly natural gas and coal, alongside solar and nuclear, which emit almost no CO₂ while running.
- A3. $(405 - 143) \div 405 \approx 65\%$ reduction.

Part B

- B1. $411 \text{ gal} \times 8,887 \text{ g/gal} \approx 3,650,000 \text{ g} \approx 3.65 \text{ t}$.
- B2. $3,147 \text{ kWh} \times 326 \text{ g/kWh} \approx 1,030,000 \text{ g} \approx 1.03 \text{ t}$.
- B3. The tool shows about 4.4 t and 1.1 t. It adds the CO₂ from drilling, refining and transporting gasoline, and from mining and shipping power-plant fuel.

Part C

Test	Model Y (g/mi)	CR-V (g/mi)	EV payback (mi)	Why
West Virginia	318	405	about 23,900	Coal-heavy grid; the gas car doesn't use the grid
Washington	85	405	about 7,100	Mostly hydropower
5,000 mi/yr	143	405	about 8,600 (1.7 years)	Same miles to pay back, more years to reach them
25,000 mi/yr	143	405	about 8,600 (4 months)	Same miles, reached sooner
Cold winters	154	422	about 8,200	Both lose efficiency; batteries and cabin heating cost the EV 20%, the gas car 8%

- C1. The plug-in hybrid rises to 406 g/mi, slightly above the CR-V. Its electric miles run on coal power and its battery adds manufacturing emissions, so it never pays back there.
- C2. The extra CO₂ to build the car and the CO₂ saved per mile don't depend on yearly mileage, so the break-even distance is fixed; driving more just reaches it sooner.
- C3. All 50 states plus DC. Vermont is cleanest (about 56 g/mi), with almost no fossil-fuel generation in the state; note that eGRID counts power where it is generated, not where it is used.

Exit ticket: strong answers name the grid as the deciding factor and cite a number, for example 143 vs. 405 g/mi in Arizona, or the near-tie for the plug-in hybrid in West Virginia.

Teaching notes

The most common stumble is forgetting to reset between Part C tests, so build a “reset first” habit early.

Misconceptions to watch for

- “EVs have zero emissions.” The bar shows manufacturing and power-plant emissions; the tailpipe is only one source.
- “Batteries make EVs worse overall.” The building segment is larger, but in most states it is repaid within the first year or two of driving.
- “Smog and CO₂ are the same thing.” CO₂ warms the planet; smog-forming NO_x and VOCs harm local air. EVs and hybrids score better on both, for different reasons.
- “Hybrids plug in.” Only plug-in hybrids charge from the grid; a regular hybrid recharges through braking and its engine.

Differentiation

- Support: provide the Part A table pre-filled for one car as a model; allow calculators for Part B; pair students deliberately.
- Challenge: run Part E; or have students design a policy (a grid change, a mileage pattern, a vehicle choice) that cuts a commuter's lifecycle CO₂ by half, and prove it in the lab.
- Cost extension: the companion tool, Drivetrain Cost Lab for Car Shoppers, adds purchase price, loans, leases and insurance. Ask whether the lowest-emission car is also the cheapest per year in your state.

Technology setup

- Open the lab on a student device before class to confirm your school's network allows it.
- No accounts or logins are needed, and the lab collects no student data. Settings are saved only in each browser.
- Projecting the lab during the Launch helps students find the right rows quickly.

Where the numbers come from

The lab uses EPA fuel-economy ratings, EPA eGRID2023 state grid emissions, Argonne National Laboratory's GREET figures for gasoline, ICCT and Argonne estimates for vehicle manufacturing, and University of Michigan lifetime-mileage estimates. Its “How the numbers are calculated” section explains every step, so students can check any value by hand.

Discussion questions for any format

1. Why does the EV's result change so much between states while the gas car's barely moves?
2. A gas car pollutes at its tailpipe; an EV's pollution happens at a power plant. Who breathes each, and how does that connect to environmental justice?
3. When would a regular hybrid be the lower-emission choice over a plug-in hybrid?
4. What would have to change for an electric car to emit more than a gas car over its life?