Module 3: Activity 3

Driving Choices: Calculating Car Emissions

IT'S OUR AIR

SUMMARY

In North Carolina, vehicles are among the largest sources of air pollution. In this activity, students will use data from the Environmental Protection Agency and the Department of Energy to compare the air pollution emitted by different cars, including an all-electric vehicle. They will calculate the emissions that result from charging an electric car in North Carolina, Seattle, and the U.S. (on average). Finally, students will also consider ways to reduce emissions through driving behavior and car maintenance.

ESSENTIAL QUESTIONS

- Do electric vehicles cause air pollution?
- How can I reduce air pollution emissions without buying a different car?
- If I'm going to buy a car, is a new hybrid or electric vehicle the best choice for reducing emissions?

TIME NEEDED

For AP and honors classes, allow one 90-minute block period for Parts A and B, and half a period for Part C. For academic earth science classes, the activity will take two full block periods.

North Carolina ESSENTIAL STANDARDS FOR EARTH/ENVIRONMENTAL SCIENCE

- EEn.2.5.5 Explain how human activities affect air quality.
- EEn.2.8.1 Evaluate alternative energy technologies for use in North Carolina.
- Other standards: HS.TT.1.1 and HS.TT.1.3. (See Resources section for explanation.)

A product of the NC Air Awareness Program 2016.

MAKING CONNECTIONS

Most environmental issues can be addressed from various angles: federal regulations, state regulations, the work of community groups, and personal choice. For example, protecting endangered species may involve a regulation against poaching and/or it may involve consumers declining to purchase products such as rhino horns or elephant tusks harvested from those animals. With respect to cars, Environmental Protection Agency (EPA) regulations that were phased in from 2004 to 2007 have resulted in much cleaner cars. But that doesn't mean that personal choices aren't important. When buying a new or used car, consumers can choose cars that emit fewer pollutants. These days, there are more choices in fuel types and vehicle models than ever before. And no matter the car, anyone can reduce emissions by driving less, driving more efficiently, and maintaining their car properly.

BACKGROUND

COMBUSTION

Air pollution creates or exacerbates many serious health problems. The primary cause of air pollution is combustion, which occurs in many settings. Examples include a forest fire, an oil-burning furnace, a coal-fired electric power plant, an outdoor grill, or vehicle engines. In fact, in North Carolina, vehicles are among the largest sources of air pollution.

Burning fuel, such as gasoline or diesel, in an internal combustion engine creates emissions of air pollutants such as particulate matter, volatile organic compounds, carbon monoxide, and nitrogen oxides (NO_X). Charging an electric car using electricity from a power plant that burns fossil fuels (such as coal and natural gas) also creates air pollution emissions. For more information on combustion and air pollution, see "Combustion Equations" (Module 1, Activity 2). For more information on the health effects of air pollution, see "Health Problems and Air Pollution" (Module 3, Activity 1).

In this activity, students will learn about air pollution emissions generated by cars – both internal combustion cars and electric vehicles. Although regulations have greatly reduced car emissions in recent years, personal choice comes into play when people purchase a new or used car, and in the amount and type of driving they do.

A NOTE ON SMOG

In this activity, students will be looking at the EPA Smog Rating for various makes and models of cars, so they may have questions about the meaning of the word "smog." It's thought to have originated in London in the early 1900s as a combination of "fog" and "smoke." It doesn't have a precise scientific definition, but is commonly used to refer to air pollution that is visible. However, remind your students that air pollution can also be invisible. The EPA Smog Rating takes into account a number of air pollution emissions, including NO_X, carbon monoxide, particulate matter, and other air pollutants.

EMISSION STANDARDS

There are two sets of standards relating to vehicles in the United States: the EPA standard and the California Standard. California standards go above and beyond the EPA standards; some other states besides California also use them.

In this activity, we'll focus on the EPA standards, which have evolved and changed over the years. The EPA Tier 2 standard began in 2004 and was phased-in for model years 2004-2007. It categorizes tailpipe emission levels into different "Bins," labeled 1-11. By the end of the implementation period, all cars were required to meet a standard of 0.07 grams of NO_X per mile. (Note: Phase-in of the next level of emission standards, called Tier 3, begins in 2017, with full implementation required by 2025.)

The standards only apply to new cars; people aren't required to junk their older cars that don't meet the new standards! According to a research firm called IHS Automotive, of the 253 million cars on American roads in 2014, the average age was 11.4 years. That means there are plenty of cars on the road that do not meet the standard of 0.07 grams of NO_X per mile. This is particularly relevant if you're looking to buy a used car and want to limit air pollution emissions. And it's where the EPA Smog Rating comes in handy.

ELECTRIC CARS

There are now many different kinds of cars on the market that use electricity for part or all of their power. Review some of the different types with your students.

A hybrid car, such as the Toyota Prius, uses energy from braking (called "regenerative braking") to recharge the drive-train battery. The battery helps power the car at certain times, reducing the need for gasoline. The car is never plugged into an electric outlet and never receives power from an electric power plant.

An all-electric car – such as the Nissan Leaf, Chevy Spark, or Tesla – has only an electric motor run by a battery. The battery is charged by plugging it into an electric outlet. The car has no internal combustion engine and no tailpipe emissions.

A plug-in electric car with an internal combustion engine, such as the Ford C-Max Energi, has a fuel tank and a plug. The battery is powered by an electric power plant, and the internal combustion engine is powered by gasoline (or other fuel) if the battery runs out of juice.

Both the Nissan Leaf and the Ford C-Max Energi can be referred to as "plug-in" cars; however, the former has no fuel tank or internal combustion engine, while the latter does, allowing for driving longer distances.

EMISSIONS ASSOCIATED WITH ELECTRIC VEHICLES

Some people think all-electric vehicles have no emissions. It's true there are no tailpipe emissions, but air pollution is emitted at electric power plants. You can figure out the emissions associated with generating the electricity for an electric vehicle (as students will do in this activity) if you know how much electricity the car uses, and if you know your electric company's fuel mix – that is, the types and amounts of fuels used to generate electricity.

Different electric vehicles use different amounts of electricity. A report from the California Air Resources Board from 2003 says electric vehicles typically use a little less than half a kilowatt-hour (kWh) of electricity per mile. The Ford Focus Electric uses about a third of a kWh per mile. (For a review of kilowatt-hours and megawatt-hours as well as other energy units, see the provided handout entitled "Energy, Electricity, Emissions, and Units.")

The emissions associated with charging the battery of an electric vehicle vary according to the fuel mix used by an electric company. In different parts of the country, the fuel mix of an electric company may be quite different. For that reason, it's interesting to compare the power plant emissions associated with charging an electric car in different parts of the country, as students will be doing in this activity. For example, coal from West Virginia and other east coast mines tends to be high in sulfur, whereas coal used in Washington state is not. These differences are due to natural differences in the composition of coal in different localities. And, as students will learn, electric companies in Washington state rely on coal less than electric companies in North Carolina. There are also differences in state regulations affecting power plants, and these differences result in different levels of emissions.

Another interesting factor to consider with plug-in electric vehicles is the timing and the location of emissions from electric power plants. Electric vehicles are most likely to be plugged in overnight, so the resulting air pollution emissions are less likely to contribute to ground-level ozone pollution, which needs heat and sunlight to occur. In contrast, cars powered by internal combustion engines emit pollutants when and where they are being used, which is often during the daytime (contributing to ozone formation) and in populated areas (where there are lots of people breathing the air).

To further complicate the comparison, cars with internal combustion engines also have additional emissions that are not tailpipe emissions. There are emissions associated with mining fossil fuels, refining them, and transporting them. Considering all the resources that go into the manufacture of vehicles, their fuels, how they are used, and how they are disposed is called life-cycle analysis. It's a good way to compare the impact of any two cars, but analyzing the full life-cycle is beyond the scope of this activity. This activity will focus only on comparing the air pollution emissions associated with operating several different cars.

OTHER FUELS

This activity focuses on cars that run on gasoline, diesel fuel, or electricity. However, there are other fuels in use, including biodiesel, natural gas, propane, ethanol, and hydrogen, to name a few. For more information about alternative fuels, see the Resources section below.

MATERIALS

- Access to the internet
- Access to computers or electronic devices suitable for completing and sharing a presentation

DRIVING CHOICES & AIR POLLUTION VIDEO

- Reviews the three major strategies for finding solutions to air pollution: societal and personal choices, regulation, and technology.
- Introduces the personal driving choices we have in choosing what we drive and how we drive and the impact those choices can have on air pollution.
- Highlights alternative transportation choices to driving alone: carpools, public transportation.

Video Length: 14:45 minutes
Key Elements: animation, interviews, video footage

WARMUP

ASK THE CLASS:

- What is the "best" car for the environment? Why?
- Are electric cars "zero emission"?
- Are there ways to reduce emissions without getting a different car?

Show the video, "Driving Choices and Air Pollution." If practical, you could have the students watch the video at home the day before you do the activity in class.

If necessary, review the units of electricity (kilowatt-hours) and natural gas (therms) with your students. See the provided handout titled "Energy, Electricity, Emissions, and Units" for more information.

Teacher Tips

This activity uses the EPA's Power Profiler website (www.epa.gov/energy/power-profiler), which can experience problems and delays if an entire class of students tries to access it on multiple computers at once. To avoid this, either get the data together as a class on one computer or call the Power Profiler office ahead of time at 202-343-9282. You can access Power Profiler on iPads, although the layout is not as clean as on a desktop computer.

– Mark Townley

THE ACTIVITY

PART A: Comparing Emissions

In this part of the activity, you will compare the emissions of the following cars:

- two 2004 cars, which don't meet Tier 2 standards
- one internal combustion car from 2015
- one plug-in electric car from 2015
- optional: one or more additional cars of your choice

Fill in the EPA Smog Rating in the table below by going to www.fueleconomy.gov and following these instructions:

- Under "Find & Compare Cars," click on "Compare Side-by-Side."
- Enter Year, Make, and Model for four cars.
- Click "Compare."
- Choose the "Energy and Environment" tab.
- **Important**: You must indicate the state where the car to get the EPA Smog Rating.

To fill in the **next three columns**, use the information in the Tailpipe NO_x Emissions table on the next page to convert EPA Smog Rating into the amount of nitrogen oxides (NO_x) a car emits. (The EPA Smog Rating also takes into account emissions of carbon monoxide, formaldehyde, particulate matter, and non-methane organic gas/non-methane hydrocarbons, or total hydrocarbons, but we're only considering NO_x here because it's the main ingredient in ozone pollution.) Notice that you need to know the model year of the car in order to translate Smog Rating into NO_x emissions.

Smog Ratings and Nitrogen Oxides (NO_x) Tailpipe Emissions for a Variety of Cars [ANSWER KEY]

Make, Model, and Year	EPA Smog Rating	Grams of NO_x emitted by the car per mile	Grams of NO_x per year (assume 15K miles/year)	Pounds of NO_x per year (1 gram =0.0022 pounds)
2004 Honda Civic (1.7 L, 4 cyl, automatic 4-spd)	[1]	[0.6]	[9,000]	[20]
2004 Ford Focus (2.0 L, 4 cyl, automatic 4-spd)	[2]	[0.3]	[4,500]	[9.9]
2015 Ford Focus 4WD (2 L, 4 cyl, automatic)	[7]	[0.03]	[450]	[0.9]
2015 Ford Focus Electric (Automatic)	[10]	[0]	[0]	[0]
(Optional) Car of your choice:				
(Optional) Car of your choice:				
(Optional) Car of your choice:				

Tailpipe NO_x Emissions: EPA Smog Rating and Bin Numbers

EPA Smog Rating (10 is best)				NO_x Tailpipe Emission Limit in grams/mile	Bin*
Model Year 2000-2008	Model Year 2009-2010	Model Year 2011-2013	Model Year 2014-2016		
10	10	10	10	0	Bin 1
9	9	8	9.8	0.02	Bin 2
8	8	7	7	0.03	Bin 3
7	7	6	6	0.04	Bin 4
6	6	5	5	0.07	Bin 5
5	5	4	4	0.10	Bin 6
4	4	3	3	0.15	Bin 7
3	3	2	2	0.20	Bin 8
2	–	–	–	0.30	Bin 9
1	–	–	–	0.60	Bin 10
0	–	–	–	0.90	Bin 11

Sources: www.epa.gov/greenvehicles/you/smog.htm and www.epa.gov/oms/standards/light-duty/tier2stds.htm

*__NOTE__: "Bin" is a word and a concept used in federal regulations. It's a way of grouping different levels of emissions. You don't need the bin numbers for this activity, but they are included on this table as a reference in case you come across the term elsewhere. Notice that the emission limit for each bin is always the same, even though the EPA Smog Ratings change for different model year cars.

After completing the table, answer the following questions:

1. Looking at the 2004 cars, you can see that cars of similar size and age emit different amounts of nitrogen oxides (NO_x). Is this surprising to you? What factors might account for this? [**Answer**: depends on engine configuration, size, and design]
2. What is the ratio of NO_x emissions of the 2004 Honda Civic compared to the 2004 Ford Focus? [**Answer**: 2 to 1]
3. Describe the difference in the tailpipe emissions of NO_x between the 2015 cars and the 2004 cars. What might explain the difference? [**Answer**: The 2015 cars emit much less NO_x than those manufactured in 2004. The 2015 internal combustion cars emit fewer emissions because of federal regulations. The electric 2015 car emits zero tailpipe emissions because it is powered by a battery.]
4. Even though the electric car does not have a tailpipe (and therefore no tailpipe emissions), using it does result in air pollution emissions. Where are the NO_x and other compounds emitted? Explain. [**Answer**: The electric car runs on electricity and when electricity is generated there are emissions at the power plant.]

PART B: Do Electric Cars Have Emissions?

Fill in the following two tables using the information about the power plant emissions in North Carolina (zip code 27608), in Seattle, Washington (zip code 98105), as well as the national averages, all available at the EPA Clean Energy website called Power Profiler: http://oaspub.epa.gov/powpro/ept_pack.charts

- Enter the zip code.
- Click View Report.
- You should be in the "Electricity Generation in Your Region" tab: all the information you need is in the tab.
- Scroll down.
- On the Fuel Mix graph, hover over each color to see the percentage.
- Scroll down below that to see the emissions for the region as well as the national average emissions.

Notice that the emission data on the website is given as pounds per megawatt-hour (MWh). Remember that 1 MWh = 1,000 kWh.

Fuel Mix for Electric Utilities [ANSWER KEY]

NOTE: These numbers were accessed from Power Profiler in October 2015 and are based on data from 2012. Check the Power Profiler website for updated data.

	% Coal	% Natural Gas	% Oil	% Nuclear	% Hydro	% Non-hydro Renewables
Electric utility in NC (27608)	[34.8]	[20.2]	[0.2]	[41.2]	[0.9]	[2.5]
Electric utility in Seattle (98105)	[24.5]	[10.7]	[0.3]	[3.2]	[52.2]	[8.8]
National Average	[37.4]	[30.3]	[0.7]	[19]	[6.7]	[5.4]

Electric Utility Emissions of Nitrogen Oxides and Sulfur Dioxide [ANSWER KEY]

NOTE: These numbers were accessed from Power Profiler in October 2015 and are based on data from 2012. Check the Power Profiler website for updated data.

	Pounds of NO_x emitted per megawatt-hour (MWh) 1 MWh = 1,000 kWh	**Pounds of SO_2 emitted per megawatt-hour (MWh)**
Electric utility in NC (27608)	[0.7]	[1.1]
Electric utility in Seattle (98105)	[0.7]	[0.8]
National Average	[0.9]	[1.9]

Using the data you've collected, fill in the following table:

Emissions from Driving an Electric Car in North Carolina and in Seattle [ANSWER KEY]

NOTE: These numbers were accessed from Power Profiler in October 2015 and are based on data from 2012. Check the Power Profiler website for updated data.

NOTE: Assume cars are driven 15,000 miles per year.	**Kilowatt-hours per year (assume 23 kWh per 76 miles) Give answer in MWh**	**NO_x in lbs/year**	**SO_2 in lbs/year**
Ford Focus Electric in NC (27608)	[4.5 MWh]	[4.5 x 0.7 = 3.2]	[4.5 x 1.1 = 5.0]
Ford Focus Electric in Seattle (98105)	[4.5 MWh]	[4.5 x 0.7 = 3.2]	[4.5 x 0.8 = 3.6]
National Average	[4.5 MWh]	[4.5 x 0.9 = 4.1]	[4.5 x 1.9 = 8.6]

Source for 23 kWh/76 miles: www.plugincars.com/ford-focus-electric

Answer the following questions:

1. According to the home page of the Power Profiler website, what date was the site last updated? What year was the data from? [**Answer will vary over time**.]
2. Compare the power plant emissions due to charging the electric car in North Carolina and in Seattle. In which location would charging the battery result in higher emissions of sulfur dioxide? [Answer: North Carolina] Why might this be? [**Answer**: because coal on the East Coast is higher in sulfur, plus in 2016, NC relies more on coal (may change in the future).]
3. Is the national average of sulfur emissions higher or lower than that in Seattle and North Carolina? Why might this be? [**Answer**: higher, because the national average has a higher percentage of fossil fuels [coal, natural gas, oil] than either Seattle or NC]
4. Gasoline-powered vehicles almost always emit much less sulfur dioxide than electric vehicles (unless the electric vehicles are being charged with electricity generated solely from nuclear, solar, wind, or hydro power). What about NO_x? Compare the amount of emissions of NO_x in pounds per year for the electric Ford Focus to the 2004 and 2015 models of the gasoline-powered Focus. Which results in the most emissions and which results in the least emissions of NO_x? [**Answer**: The 2015 gasoline-powered Focus emits less NO_x than the electric Ford Focus. The 2004 gasoline-powered Focus emits the most NO_x of all three cars.]

Challenge Questions

5. Is it accurate to compare emissions resulting from generating electricity to charge the battery to emissions from burning fuel in an internal combustion vehicle? Why or why not? [**Answer**: No, because we haven't considered the emissions associated with mining, refining, and transporting the fossil fuel used in the gasoline-powered Ford Focus.]
6. Compare the location of emissions of NO_x and sulfur dioxide for the electric Ford Focus to the gasoline-powered Ford Focus. [**Answer**: Those emissions are produced at the electric power plant rather than coming out of the tailpipe.]
7. Compare the timing of the emissions of NO_x and sulfur dioxide for the electric Ford Focus to the gasoline-powered Ford Focus. [**Answer**: The emissions are not produced while driving, but while charging, which may often be at night.]
8. Nitrogen oxides (NO_x) are a main ingredient in ground-level ozone pollution. Remember that ozone is formed by a reaction of NO_x and volatile organic compounds in the presence of heat and sunlight. It is more likely to form on sunny summer afternoons. Considering the timing of NO_x emissions, is an electric or gasoline Ford Focus more likely to contribute to ozone pollution? Explain your answer. [**Answer**: An electric car may be charged at night, when ozone formation is not an issue.]
9. Discuss the pros and cons of "moving" car emissions from the tailpipe to the electric power plant. [**Possible answers**: Emissions are more easily controlled at central locations rather than at millions of individual tailpipes. Electric cars can be charged at night, making use of available capacity and switching emissions of ozone ingredients to a time of day when ozone is less likely to form. Some consumers may think their electric cars are not responsible for any air pollution emissions since the emissions occur elsewhere. Using a central power source rather than an on-board power source creates "range anxiety" for drivers.]
10. Is an all-electric vehicle emission free? Why or why not? Can an electric car be emission free? [**Answer**: Electric cars do not give off emissions of air pollution during driving, but they do result in emissions at the electric power plant because they use electricity to charge the battery. If the battery were charged with 100% renewable resources (wind, solar, or hydropower), the car could be said to be emission free.]

PART C: Using Less Gas

In Parts A and B you compared cars and learned information that might be helpful if you are in the market for a new or used car. But what if you're not planning to buy a car right now? There are plenty of ways to reduce the emissions from your current car and improve air quality. Break into groups and make a list of as many as you can. [**Possible answers**: Use alternate transportation by carpooling, taking public transportation, or walking/biking; drive wisely by reducing time spent idling, avoiding jackrabbit starts, coasting when approaching a stop sign, avoiding the drive-through, and maintaining your car properly (especially tire pressure).]

Come up with a slogan and art for a bumper sticker to encourage people to reduce emissions from their cars.

WRAP UP AND ACTION

In small groups, create a PowerPoint or multi-media presentation encouraging people to think about air pollution when purchasing a new or used car, and while driving their current car.

In a class discussion, consider what type of car is "best" for the environment and whether there is more than one "right" answer. How might the answer differ for someone who commutes 50 miles to work compared to someone who makes short trips close to home? Challenge students to consider the implications of emissions associated with the mining, refining, and transport of fossil fuels as well as the emissions associated with battery manufacture and disposal. Many of these issues do not yet have clear answers.

ASSESSMENT

HAVE STUDENTS:

- Write an article for the school newspaper or a blog giving practical advice to fellow students about how to help reduce air pollution when purchasing a new or used car. Articles could be shared on school-sponsored social media sites or blogs if applicable.
- Choose a used car to buy given $5,000 and a desire to reduce emissions of air pollution. Have them provide the reasoning for their choice.

EXTENSIONS

Students might be interested to learn more about the emissions produced by school buses in the United States. Pollution from older diesel school buses contributes to air quality problems and is a health concern for the millions of students who ride them. The EPA's "Clean School Bus USA" is a program designed to help decrease unnecessary school bus idling, retrofit existing buses to reduce emissions, and replace the oldest buses with buses that put out much fewer emissions. In North Carolina, school districts make it a priority to reduce emissions by having a no-idle policy, retrofitting all eligible buses with exhaust emission controls, and replacing old buses with new ones that create fewer emissions.

Students may enjoy doing research on cutting-edge vehicle designs. For example, Tesla: www.teslamotors.com; the solar and people-powered ELF: http://organictransit.com/; Elio: www.eliomotors.com/

Have students research the specific technologies that have reduced tailpipe emissions in vehicles in the past several decades.

Electric vehicles result in much lower emissions of carbon dioxide than traditional internal combustion engines. Compare the emissions of carbon dioxide between the 2015 Ford Focus gasoline car and the 2015 Ford Focus electric car. On the website www.fueleconomy.gov, under "Find and Compare Cars," you can see tons of carbon dioxide for gasoline cars (under "Energy and Environment") and you can calculate emissions of greenhouse gases based on your zip code to take into account the fuel mix used by your electric utility. In order to do this, you need to choose "tailpipe and upstream greenhouse gases (GHG)." Otherwise, the default is to show "tailpipe" emissions, which is zero for an electric car. When you calculate the emissions, the answer will be in grams per mile, so make sure you switch to grams per mile as the unit for the gasoline powered cars to compare apples to apples.

Electric vehicles may be more expensive to purchase than more traditional models, but they are usually less expensive to drive and don't require as much routine maintenance. Have students conduct a cost-benefit analysis between a gasoline-powered and an electric-powered model of the same car (for example, the gasoline Ford Focus vs. electric Ford Focus).

Some students might wonder if the improved emissions in newer cars compared to older cars are simply due to better mileage in the new cars. The answer is no – improved emissions technology means new cars that get worse mileage than old cars can still have lower emissions. Students can check this out for themselves on www.fueleconomy.gov by comparing old and new cars with similar mileage. In order to do this, it's best if they use the unfamiliar units of gallons per mile rather than miles per gallon. That's because it will be more consistent with the pollutants per mile that students analyzed in the activity.

RESOURCES

More information about idle reduction from the U.S. Department of Energy and the North Carolina Division of Air Quality:

http://deq.nc.gov/about/divisions/air-quality/motor-vehicles-air-quality/idle-reduction

http://deq.nc.gov/about/divisions/air-quality/motor-vehicles-air-quality/idle-reduction/faqs

http://deq.nc.gov/about/divisions/air-quality/motor-vehicles-air-quality/idle-reduction/turn-off-your-engine-campaign

Plug in America is a nonprofit group that offers information about hybrid and all-electric cars on its website:

www.pluginamerica.org

More information about other alternative fuels, including biodiesel, natural gas, ethanol, hydrogen, and propane:

www.afdc.energy.gov/

More information about efficient driving habits:

www.ncdot.gov/travel/drivegreen/

More information about different kinds of EV's:

www.afdc.energy.gov/uploads/publication/hybrid_plugin_ev.pdf

OTHER NORTH CAROLINA ESSENTIAL STANDARDS

HS.TT.1.1 Use appropriate technology tools and other resources to access information (multi-database search engines, online primary resources, virtual interviews with content experts).

HS.TT.1.3 Use appropriate technology tools and other resources to design products to share information with others (e.g. multimedia presentations, Web 2.0 tools, graphics, podcasts, and audio files).

Energy Review
Page 1

Energy, Electricity, Emissions, and Units

What is Energy?

In physics, energy is the ability to do work. In daily usage, the word energy means the power to accomplish something: "I don't have the energy to finish my homework." or "My hot water heater died and I want to buy one that uses less energy." In It's Our Air, energy generally refers to resources used to power lights, appliances, air conditioners, furnaces, and vehicles. This energy can take many forms. A few examples: a hot water heater that runs on natural gas, a wood stove that burns wood, a furnace that uses oil, an air conditioner that's powered by electricity, a car that runs on gasoline. Thinking back a generation or two, mills were powered by the energy of rivers, and wagons were powered by horses or oxen.

What is Electricity?

Electricity is a type of energy that consists of electrons flowing from one atom to another. Electric power plants use generators to push electrons to homes, businesses, and industry through power lines. Electricity can be produced in many ways: by burning fossil fuels such as coal or natural gas, through nuclear fission, or by harnessing the power of the sun, wind, or water.

Review of Units

Joule (J): A unit of energy. It equals the force required to accelerate one kilogram at the rate of one meter per second squared through one meter of space.
$J = (kg \times m^2)/s^2$

British thermal unit (BTU or Btu): A unit of thermal (heat) energy. It is the heat required to raise the temperature of one pound of water by one degree Fahrenheit. It equals approximately 1,055 joules.

Watt (W): A unit of power. Power refers to the rate at which energy is produced or consumed. A watt is equal to 1 joule of energy per second.
$W = J/s$

Kilowatt (kW): A unit of power. It equals 1,000 watts or 1,000 joules of energy per second.

Watt-hours (Wh): A unit of energy. It is the multiplication of power in watts (joules/second) by an hour. It equals 3,600 joules.

Kilowatt-hour (kWh): A unit of energy equal to 1,000 watt-hours. It is the multiplication of power in kilowatts by an hour. A kilowatt-hour equals 3.6 megajoules (3.6 million joules). A kilowatt-hour also equals approximately 3,412 Btu.

Megawatt-hour (MWh): A unit of energy equal to 1,000 kilowatt-hours. It is the multiplication of power in megawatts by an hour.

Therm: A unit of heat. On a bill from the natural gas company, energy use is measured in "therms." One therm equals 100,000 Btu.

Energy, Electricity, Emissions, and Units (continued)

Emissions from Burning Natural Gas, Oil, Coal

Pounds of Pollutant per Billion Btu of Energy Input
Note: 1 billion Btu of natural gas = 10,000 therms.

Pollutant	Natural Gas	Oil	Coal
Carbon dioxide	117,000	164,000	208,000
Carbon monoxide	40	33	208
Nitrogen oxides	92	448	457
Sulfur dioxide	0.6	1,122	2,591
Particles	7	84	2,744
Mercury	0.000	0.007	0.016

Source: Natural Gas 1998: Issues and Trends (Energy Information Administration) Chapter 2, page 58.
www.eia.gov/oil_gas/natural_gas/analysis_publications/natural_gas_1998_issues_and_trends/it98.html

Emissions from Generating Electricity

Different utilities use different fuels to generate electricity, depending on the resources available in that part of the country: coal and other fossil fuels, hydropower, nuclear, solar, wind, biomass, etc. For this reason, the emissions that result from generating a kilowatt-hour of electricity vary as well. The EPA Clean Energy website has a page called "Power Profiler" where you can enter your zip code and find out the mix of fuels used by your electric utility and the emissions that result: http://oaspub.epa.gov/powpro/ept_pack.charts

Energy Conversion Calculator

You can convert energy from one unit to another using this information on this handout. Another option is to use an online energy conversion calculator, such as this one:
www.eia.gov/kids/energy.cfm?page=about_energy_conversion_calculator-basics

Driving Choices: Calculating Car Emissions

Student Page Part A: Page 1

PART A: Comparing Emissions

In this part of the activity, you will compare the emissions of the following cars:

- two 2004 cars, which don't meet Tier 2 standards
- one internal combustion car from 2015
- one plug-in electric car from 2015
- optional: one or more additional cars of your choice

Fill in the EPA Smog Rating in the table below by going to www.fueleconomy.gov and following these instructions:

- Under "Find & Compare Cars," click on "Compare Side-by-Side."
- Enter Year, Make, and Model for four cars.
- Click "Compare."
- Choose the "Energy and Environment" tab.
- **Important**: You must indicate the state where the car to get the EPA Smog Rating.

To fill in the **next three columns**, use the information in the Tailpipe NO_x Emissions table on the next page to convert EPA Smog Rating into the amount of nitrogen oxides (NO_x) a car emits. (The EPA Smog Rating also takes into account emissions of carbon monoxide, formaldehyde, particulate matter, and non-methane organic gas/non-methane hydrocarbons, or total hydrocarbons, but we're only considering NO_x here because it's the main ingredient in ozone pollution.) Notice that you need to know the model year of the car in order to translate Smog Rating into NO_x emissions.

Smog Ratings and Nitrogen Oxides (NO_x) Tailpipe Emissions for a Variety of Cars

Make, Model, and Year	EPA Smog Rating	Grams of NO_x emitted by the car per mile	Grams of NO_x per year (assume 15K miles/ year)	Pounds of NO_x per year (1 gram =0.0022 pounds)
2004 Honda Civic (1.7 L, 4 cyl, automatic 4-spd)				
2004 Ford Focus (2.0 L, 4 cyl, automatic 4-spd)				
2015 Ford Focus 4WD (2 L, 4 cyl, automatic)				
2015 Ford Focus Electric (Automatic)				
(Optional) Car of your choice:				
(Optional) Car of your choice:				
(Optional) Car of your choice:				

Driving Choices: Calculating Car Emissions

Student Page Part A: Page 2

Tailpipe NO_x Emissions: EPA Smog Rating

EPA Smog Rating (10 is best)				NO_x Tailpipe Emission Limit in grams/mile
Model Year 2000-2008	Model Year 2009-2010	Model Year 2011-2013	Model Year 2014-2016	
10	10	10	10	0
9	9	8	9.8	0.02
8	8	7	7	0.03
7	7	6	6	0.04
6	6	5	5	0.07
5	5	4	4	0.10
4	4	3	3	0.15
3	3	2	2	0.20
2	–	–	–	0.30
1	–	–	–	0.60
0	–	–	–	0.90

Sources: www.epa.gov/greenvehicles/you/smog.htm and www.epa.gov/oms/standards/light-duty/tier2stds.htm

After completing the table, answer the following questions:

1. Looking at the 2004 cars, you can see that cars of similar size and age emit different amounts of nitrogen oxides (NO_x). Is this surprising to you? What factors might account for this?

2. What is the ratio of NO_x emissions of the 2004 Honda Civic compared to the 2004 Ford Focus?

3. Describe the difference in the tailpipe emissions of NO_x between the 2015 cars and the 2004 cars. What might explain the difference?

4. Even though the electric car does not have a tailpipe (and therefore no tailpipe emissions), using it does result in air pollution emissions. Where are the NO_x and other compounds emitted? Explain.

Driving Choices: Calculating Car Emissions

Student Page Part B: Page 1

PART B: Do Electric Cars Have Emissions?

Fill in the following two tables using the information about the power plant emissions in North Carolina (zip code 27608), in Seattle, Washington (zip code 98105), as well as the national averages, all available at the EPA Clean Energy website called Power Profiler: http://oaspub.epa.gov/powpro/ept_pack.charts

- Enter the zip code.
- Click View Report.
- You should be in the "Electricity Generation in Your Region" tab: all the information you need is in the tab.
- Scroll down.
- On the Fuel Mix graph, hover over each color to see the percentage.
- Scroll down below that to see the emissions for the region as well as the national average emissions.

Notice that the emission data on the website is given as pounds per megawatt-hour (MWh). Remember that 1 MWh = 1,000 kWh.

Fuel Mix for Electric Utilities

	% Coal	% Natural Gas	% Oil	% Nuclear	% Hydro	% Non-hydro Renewables
Electric utility in NC (27608)						
Electric utility in Seattle (98105)						
National Average						

Electric Utility Emissions of Nitrogen Oxides and Sulfur Dioxide

	Pounds of NO_x emitted per megawatt-hour (MWh) 1 MWh = 1,000 kWh	Pounds of SO_2 emitted per megawatt-hour (MWh)
Electric utility in NC (27608)		
Electric utility in Seattle (98105)		
National Average		

Using the data you've collected, fill in the following table:

Emissions from Driving an Electric Car in North Carolina and in Seattle

NOTE: Assume cars are driven 15,000 miles per year.	Kilowatt-hours per year (assume 23 kWh per 76 miles) Give answer in MWh	NO_x in lbs/year	SO_2 in lbs/year
Ford Focus Electric in NC (27608)			
Ford Focus Electric in Seattle (98105)			
National Average			

Source for 23 kWh/76 miles: www.plugincars.com/ford-focus-electric

Driving Choices: Calculating Car Emissions

Student Page Part B: Page 2

Answer the following questions:

1. According to the home page of the Power Profiler website, what date was the site last updated? What year was the data from?

2. Compare the power plant emissions due to charging the electric car in North Carolina and in Seattle. In which location would charging the battery result in higher emissions of sulfur dioxide? Why might this be?

3. Is the national average of sulfur emissions higher or lower than that in Seattle and North Carolina? Why might this be?

4. Gasoline-powered vehicles almost always emit much less sulfur dioxide than electric vehicles (unless the electric vehicles are being charged with electricity generated solely from nuclear, solar, wind, or hydro power). What about NO_X? Compare the amount of emissions of NO_X in pounds per year for the electric Ford Focus to the 2004 and 2015 models of the gasoline-powered Focus. Which results in the most emissions and which results in the least emissions of NO_X?

Challenge Questions

5. Is it fair to compare emissions resulting from generating electricity to charge the battery to emissions from burning fuel in an internal combustion vehicle? Why or why not?

6. Compare the location of emissions of NO_X and sulfur dioxide for the electric Ford Focus to the gasoline-powered Ford Focus.

7. Compare the timing of the emissions of NO_X and sulfur dioxide for the electric Ford Focus to the gasoline-powered Ford Focus.

8. Nitrogen oxides (NO_X) are a main ingredient in ground-level ozone pollution. Remember that ozone is formed by a reaction of NO_X and volatile organic compounds in the presence of heat and sunlight. It is more likely to form on sunny summer afternoons. Considering the timing of NO_X emissions, is an electric or gasoline Ford Focus more likely to contribute to ozone pollution? Explain your answer.

9. Discuss the pros and cons of "moving" car emissions from the tailpipe to the electric power plant.

10. Is an all-electric vehicle emission free? Why or why not? Can an electric car be emission free?