Today I Learned About Fossil Fuels

"Oil starts out as crude oil. We drill it out of the ground and then it's refined into various products like gasolines. It may be diesel, it may be heating oil, it may be jet fuel."
John Reilly, MIT Joint Program of Science and Policy of Global Change
TILclimate podcast: Today I Learned About Fossil Fuels

What Are Fossil Fuels?

You may have heard that burning fossil fuels releases carbon dioxide (CO_2) into the atmosphere, where it acts like a blanket, trapping heat. While we need some heat-trapping blanket to support life on Earth, the extra CO_2 is trapping too much heat – warming our Earth, ocean, and air. This warming is causing dramatic changes to our climate and weather patterns. What are fossil fuels and why are they so important?

 Before the 1800s, most people burned wood, peat, or animal dung for heat, light, and energy. This is still true in many parts of the world today.

 Coal was in use in China 4,000 years ago, and in Britain 2,500 years ago. In the early 1700s, the first steam engine was invented, and the use of coal grew. Coal is a much more energy-dense fuel than wood, which means a smaller amount of coal produces much more heat. Since the 1800s and 1900s, coal has been used in factories, power plants, and to heat homes.

 Oil (also called crude oil, petroleum, rock oil, and other names) has also been in use for thousands of years, but really took off with the invention of the internal combustion engine in the 1860s. Oil generally cannot be used in the form that gets drilled out of the ground – it must be *refined* into gasoline, fuel oil, jet fuel, and thousands of other products.

 Gasoline (also called gas) is the oil product most cars and trucks use. While it is called 'gas,' it is a liquid – it is made from crude oil (petroleum) and has been in use since the 1890s. **Diesel** is also a product from crude oil and is used in many trucks and some cars.

 Natural gas (also called frack gas, methane gas, fossil gas, CNG, LNG, and other names) is often a byproduct of oil drilling and was originally treated as a dangerous gas that could explode. Beginning in the 1930s, natural gas has been used in homes for cooking, light, and heat. Since the growth of hydraulic fracturing (also called fracking) in the late 1960s, natural gas has become an increasingly common energy source for power plants and factories.

Most of the energy and electricity in the US are generated from these four fossil fuels. There are many other products made from petroleum and coal – everything from fertilizers to cosmetics.

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# Today I Learned About Fossil Fuels

Fossils?

When most people hear the phrase "fossil fuels" their first thought probably has more to do with dinosaurs than with coal, oil, and natural gas. In fact, people sometimes call petroleum products "dinosaur juice." But do fossil fuels actually come from dinosaurs? How did that oil get underground? And why are they so important?

The answer is different for oil and natural gas on the one hand and coal on the other. The formation of liquid and gas fossil fuels is a different process from that for solid coal.

The Stories of Coal and Oil

On the following pages, you will find some of the steps to form oil and coal. Each of these stories is presented out of order. Rearrange the steps to learn the long process necessary to form fossil fuels. Write the letters of each step in order.

The stories of coal and oil include millions of years. Below is a simplified timeline, showing the formation of these fossil fuels along with key moments in evolutionary history.
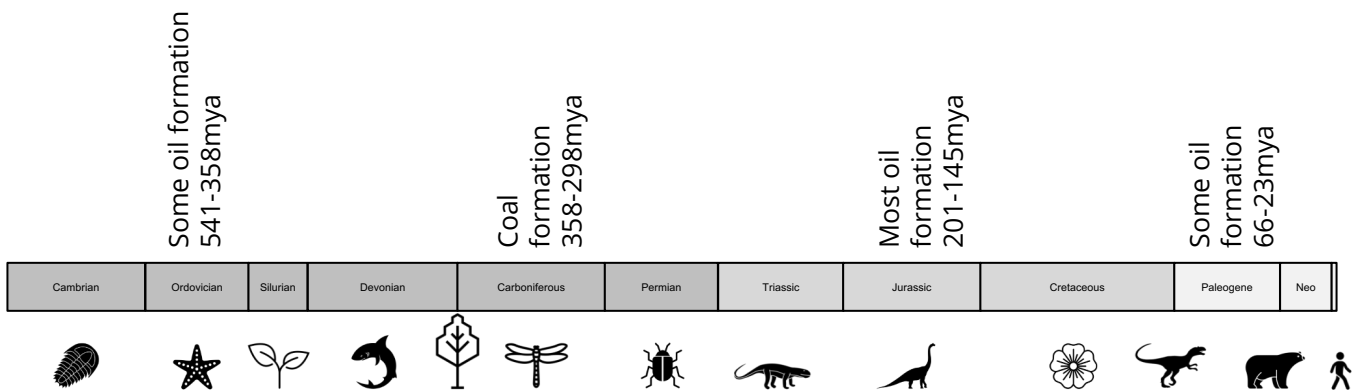
Questions

After you put each story in order, answer the following questions:

1. Why are fossil fuels considered non-renewable?

2. Is the term 'fossil fuels' accurate? Why or why not?

3. Would you expect fossil fuel reserves and deposits to be found all over the world, or only in certain places?

4. Were you surprised by any of the steps in the stories?

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The Story of Oil & Natural Gas

A. Catagenesis As the kerogen and bitumen get buried even deeper over millions of years, the pressure and temperature increases. Hot temperatures will form various grades of oil, while even hotter temperatures will create natural gas. If temperatures do not get high enough, no petroleum will form.

B. Decomposition Marine organisms die, decompose, and get buried under layers of sediment (sand, silt, and clay.) Lipids are not decomposed as quickly as proteins or carbohydrates.
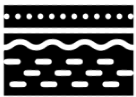
C. Diagenesis Over millions of years, sediment layers grow, adding pressure to the decomposed organic matter and increasing the temperature. This forms two new substances, kerogen and bitumen.

D. Distillation Oil and natural gas are not useable out of the ground. They are usually pumped to refineries, which can convert crude oil to many different grades of petroleum, such as bunker fuel, airplane fuel, gasoline, and diesel.

E. Extraction After millions of years underground, humans extract the fuels for use. Oil and natural gas are generally drilled out from the porous rock through the cap rock. To free up reserves that are hard to get to, liquids are pumped into harder rocks. This is called hydraulic fracturing or "fracking."
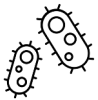
F. Growth Algae and plants in the ocean grow, converting the glucose to the proteins, carbohydrates, lipids, and lignin that they need to live. Other organisms create more of these compounds when they eat the algae and plants.

G. Impact As we burn fossil fuels like oil and natural gas, we release the carbon dioxide from photosynthesis millions of years ago. This CO_2 builds up in the atmosphere, acting like a blanket and trapping heat from the sun.

H. Photosynthesis Plants and algae use the energy of the sun, plus carbon dioxide (CO_2) and water (H_2O) to form glucose ($C_6H_{12}O_6$,) oxygen (O_2,) and water. This is the basis for almost every food web on Earth.
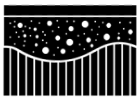
I. Saturation Liquid petroleum and natural gas seeps into the pores in certain kinds of rock (especially sandstone and limestone) like water into a sponge. If a nonporous rock has formed above the porous rock, the fuels are trapped under a "cap rock." If there is no cap rock, they can escape to the surface.

J. Use Each form of petroleum is used for a different purpose. Fossil fuels are used to produce most of the electricity in the US, as well as transportation, heating, and industrial uses.

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The Story of Coal

A. Compression Over millions of years, sediment layers grow, adding pressure to the organic matter and increasing the temperature. This forms lignite.

B. Conversion Some coal is processed into coke, tar, coal gas, and other forms for various industrial uses.

C. Decomposition Plants die, decompose, and get buried under layers of sediment (sand, silt, and clay.) During the Carboniferous period, decomposers do not yet break down lignin from trees.

D. Extraction After millions of years underground, humans mine the coal out of the ground. Mining can be underground or open-pit, depending on the depth of the coal deposit.

E. Growth Plants in coastal swamps grow, converting the glucose to the proteins, carbohydrates, lipids, and lignin that they need to live. Early trees develop more lignin than previous kinds of plants.

F. Impact As we burn fossil fuels like coal, we release the carbon dioxide from photosynthesis millions of years ago. This CO_2 builds up in the atmosphere, acting like a blanket and trapping heat from the sun.

G. Photosynthesis Plants and algae use the energy of the sun, plus carbon dioxide (CO_2) and water (H_2O) to form glucose ($C_6H_{12}O_6$,) oxygen (O_2,) and water. This is the basis for almost every food web on Earth.

H. Pressure and Heat Over millions of years, lignite continues to be pressed by layers of water, sediment, and rock, forming denser types of coal: subbituminous, bituminous, and anthracite.

I. Use Most coal is burned to generate electricity or heat. Coal is generally burned to create steam, which turns a turbine to generate electricity. In some cases, it may be burned to create heat for industrial uses or for space heating.

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"Natural gas is cleaner than coal, but it still has carbon dioxide emissions. So the challenge, the debate is – is it a bridge to a cleaner fuel or is it just a bridge to an economy heavily dependent on natural gas?"

Dr. John Reilly, MIT Joint Program of Science and Policy of Global Change
TILclimate podcast: Today I Learned About Fossil Fuels

Asking Big Questions

The future of fossil fuel use in the US and the world is a big question. We know that when we burn fossil fuels like coal, oil, and natural gas, we release carbon dioxide (CO_2) into the atmosphere. Carbon dioxide acts like a blanket, trapping heat from the sun. A regular amount of CO_2 in the atmosphere is needed for life on Earth, but the excess CO_2 is trapping extra heat. Trapped heat is warming our ocean, air, and Earth – changing weather and climate patterns all over the world.

While technologies like solar, wind, geothermal, and carbon capture are all growing, most of the energy in the US comes from high-carbon sources. Decision-makers and policy writers have big decisions to make about how to create the energy future we want – and even what that future looks like.
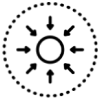

US Energy Consumption By Source, 2001-2018
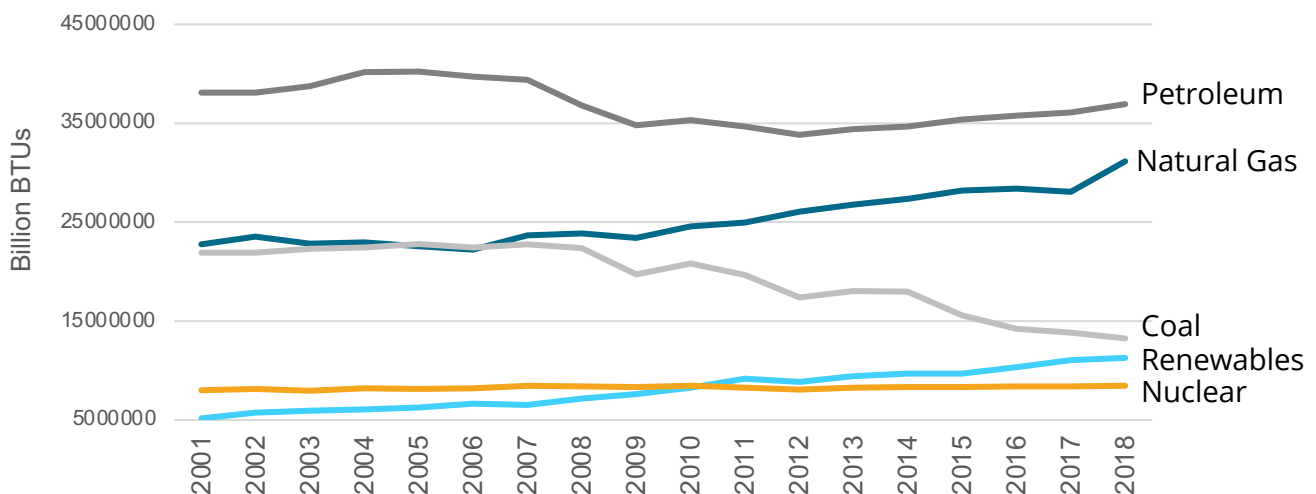
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SMART Questions

When scientists ask big questions, they design the questions so that they are *testable*. That is, they make sure that the question they are asking can be answered with the tools and time available. For example, the question "What was it like in the past?" is too broad to answer. If you ask an elder you know "What did a day in school look like for you when you were my age?" you will learn a lot about the past.

When designing a testable question, one method is to make sure your question is SMART – Specific, Measurable, Attainable, Relevant, and Time-bound. By moving your initial broad question through these steps in order, you can find a good, testable question that supports your overall investigation.

Term	Definition
Specific	**Step One: Make it concise, limited, and definite.** Could someone else answer your question without clarification? Is it clear when you have answered your question?
Measurable	**Step Two: Look for numbers, precents, locations, or estimates.** Make sure that the things you want to measure are related to one another. Terms such as larger, smaller, about the same may be acceptable.
Attainable	**Step Three: Make sure it can be answered using tools you have.** Does your question ask for data you are able to get? Do you have the tools and knowledge necessary to find your answers?
Relevant	**Step Four: Check that it is related to your project or interests.** Will answering your specific question help to answer your broad question?
Time-bound	**Step Five: Tie it to a specific time period, if necessary.** Does time affect the answer to the question? How up-to-date are your data?

Images from the Noun Project by WebTechOps, Umer Younas, Wichai Wi, Tomas Zlanabitnig, and Linseed Studio

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SMART Question Example

For this activity, you will be focusing on fossil-fuel-related maps. As an example, we will create a SMART question based on the Wind map.

Initial Question: Should the US build more wind power as an energy source?

This question is a large-scale policy question and cannot be answered with a simple answer. Any question that begins with "should" is probably very broad. We are going to use the SMART model to refine our question to make it testable.
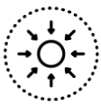
Step 1: Specific: Is the US already harnessing most of the wind power it can?

- If the US is already generating electricity from wind in as many places as possible, we might want to focus our efforts on other energy sources.

Step 2: Attainable: Where in the US has high enough wind energy resources but not very many wind power plants?

- The Wind map has layers for wind energy resources and for current wind power plants.

Step 3: Measurable: What areas of the US have medium to high wind energy resources (above 5 meters per second)? Do those areas have many wind power plants?

- The US is very large. Instead of measuring area and counting power plants, you can estimate visually by looking at the areas with high wind resources and the concentration of wind power plants. We have also refined "high enough wind energy" to a number, based on the map legend.

Step 4: Relevant: Will knowing whether there are areas of the US with high wind energy resources but not very many wind power plants help answer our overall question?

- It is a good idea to check whether your question is still related to your initial question. If most of the places with good wind resources already had wind power plants, perhaps we would decide that the US should not pursue wind power as an energy source.

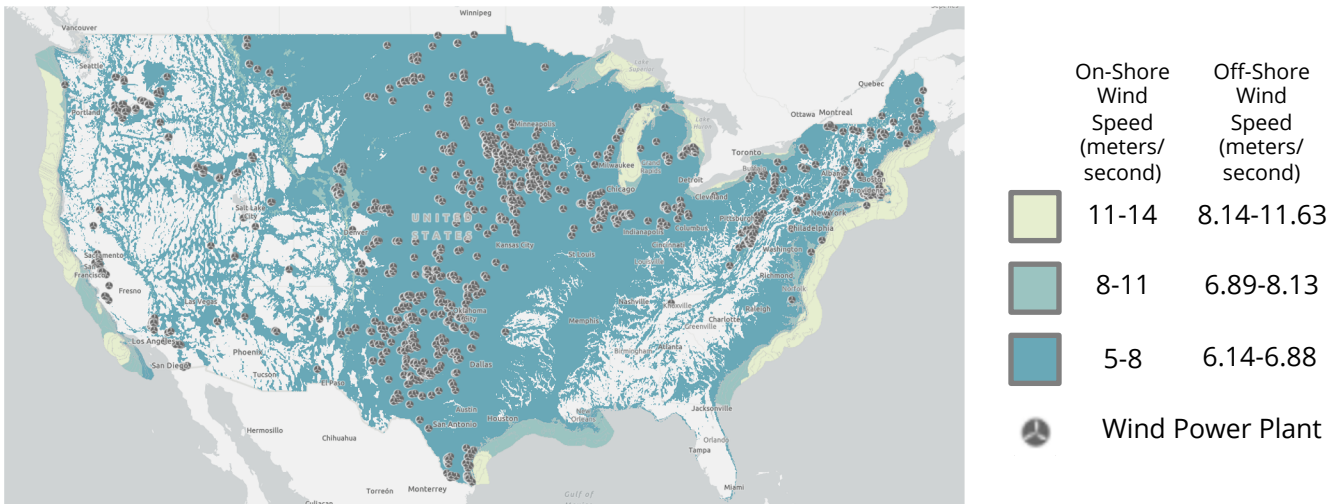**Step 5: Time-bound:** Does time affect the answer to the question?

- Time could mean within a year (variations in weather, energy use, etc. over a year) or it could refer to the data collection (when was this dataset updated?) In this case, if the wind power plant locations were not up-to-date, it might change our answer.

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SMART Question Example, Cont'd

Final Question: Where in the US has medium to high wind energy resources (above 5 meters per second) but not very many wind power plants?

This final question is specific (answerable with a relatively simple answer,) attainable (answerable with the tools available on this website,) measurable (defines its terms and uses visual estimation,) relevant (supports the overall policy question with facts,) and time-bound (looks at the most recent wind power plant data.)

	On-Shore Wind Speed (meters/second)	Off-Shore Wind Speed (meters/second)
	11-14	8.14-11.63
	8-11	6.89-8.13
	5-8	6.14-6.88
	Wind Power Plant	

Answer: Looking at the map, there are large areas of the US, especially in the upper Midwest and across the Southeast, that have significant wind resources but very few wind power plants. As well, almost all US coastal waters have significant wind resources, and there are almost no ocean-based wind power plants. The US could build more wind power as an energy source in these areas.

Other Questions

We can go back to our initial question, "Should the US build more wind power as an energy source?" We now know that it would be possible for the US to pursue wind power – that is, there are places in the US that are not yet harnessing the wind energy resources they have.

What other questions could we ask about wind power that would help policy-makers decide whether to support wind power as part of the US energy makeup?

What other questions do you have?

What other information would you need to answer those questions?

Map from the US Energy Information Administration https://atlas.eia.gov/apps/wind/explore

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"The question becomes: are we really serious about meeting the targets we have?"
Dr. John Reilly, MIT Joint Program of Science and Policy of Global Change
*TILclimate podcast: Today I Learned About Fossil Fuels*

Explore the Tools

Today, you will use an online tool to design and test a question about fossil fuels in the US. Before you begin designing your question, familiarize yourself with the tool.

1. Visit https://atlas.eia.gov/pages/energy-maps and choose one of the fossil-fuel-related maps, such as Natural Gas, Petroleum, Coal, or Fossil Fuels. For an extra challenge, you could choose "All Energy Infrastructure and Resources."

2. On your chosen map, toggle the Layers on by clicking the ⬚ icon.

3. Toggle the various layers on and off using the 👁 and 👁 icons. Use the ▷ to expand submenus.

4. Once you have chosen your preferred layers, toggle the Legend 📋 to understand what the colors mean. Pay attention to units, if there are any.

5. As you explore, write down any questions that pop into your head. It is okay if the questions are very broad at this point. You will refine them later.
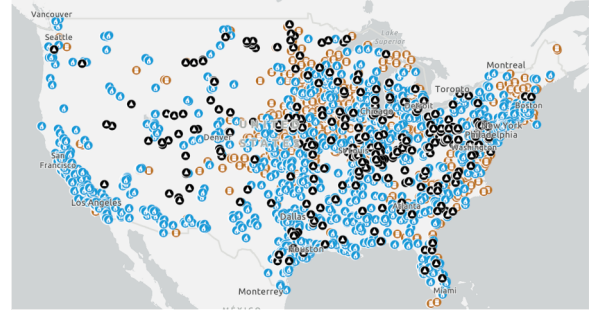

Natural Gas Wells
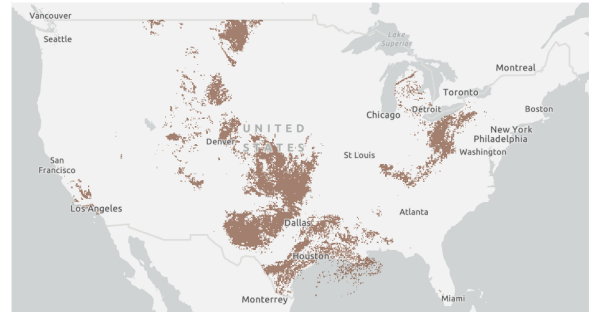
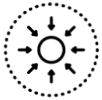Oil Wells

Coal Mines

Fossil Fuel Power Plants

All images from the US Energy Information Administration https://atlas.eia.gov/apps/fossil-fuels/explore

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Create Your SMART Question

1. Choose one of the broad questions you noted while exploring the mapping tool.

2. List some more **specific** questions that would help answer your broad question. Consider questions about locations, available resources, infrastructure, impacts, etc. Choose one of your specific questions.

3. What can be **measured** to help answer your specific question? Is it a number, an area, a distance, something else? Rewrite your question to clarify what you will be measuring.

4. What level of measurement is **attainable** with the tools and time you have? In the case of these maps, it may not be possible to count every location or get an accurate measurement of area. For many questions, visual estimation may be enough. Rewrite your question to make it answerable with your chosen map.

5. Is your question still **relevant** to your broad question? Will answering this question help inform a decision or choice in your broad question? If not, rewrite your question.

6. Is **time** a factor in your question? With these maps, time is probably not a major issue, but consider whether your question would have a different answer at different times of year, or in a different decade. Check when the dataset was last updated.

7. Look over your final question. Check it again – is it Specific, Measurable, Attainable, Relevant, and Time-bound?

Answer Your SMART Question

8. Using the mapping tool, answer your question. Depending on your question, your answer may be a simple yes/no or may be more complex.

9. Explain how your answer relates to your broad question.

10. What other questions do you have?

11. Are there other specific questions related to your broad question that could be answered using this mapping tool?

12. What other kinds of information would you need to answer your broad question?

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SMART Question Rubric

Term	A strong question…	A satisfactory question…	Redo your question if it…	Guide for Improvement
Specific	is clear, answerable, and understandable.	is clear and answerable, but not understandable.	is neither clear nor answerable.	Can someone else answer your question without clarification?
Measurable	asks for a small number of related locations, percentages, counts, or other numbers.	asks for too many related locations, percentages, counts, or other numbers.	asks for unrelated locations, percentages, counts, or other numbers.	Make sure that the things you want to measure are related to one another. Measurements may be visual estimates.
Attainable	can be easily answered with the tool available.	can be answered with the tool available, but it will take a lot of time and effort.	cannot be answered with the tool available.	Does your question line up with the available layers on your map?
Relevant	clearly supports the initial broad question and leads to other questions.	clearly supports the initial broad question but does not lead to other questions.	does not clearly support the initial broad question.	Will answering your question help to answer your initial question?
Time-bound	limits data collection and answers to a specific time period.	limits data collection or answers, but not both, to a time period.	does not limit data collection or answers by time.	Check how up-to-date your data are.