

Today I Learned About Fossil Fuels

Description:

Fossil fuels are used throughout our world. Why are they called that, and where do they come from? What are the impacts of their extraction, distribution, and use? Fossil fuels are at the center of a lot of big questions. Students develop and answer their own specific, testable questions using a data visualization website.

Skills & Objectives

SWBAT

- Explain where coal, oil, and natural gas come from.
- Understand the differences between coal, oil, natural gas, and gasoline.
- Explain why fossil fuels are considered non-renewable.
- Understand the relationship between burning fossil fuels and climate change.
- Develop, refine, and answer a specific, measurable question with a given data-visualization tool.

Skills

- Asking and answering questions
- Data visualization and analysis
- Logical sequencing

Students Should Already Know That

- The burning of fossil fuels releases carbon dioxide into the atmosphere, where it acts like a blanket, trapping heat. A regular amount of carbon dioxide is needed to support life on Earth, but excessive carbon dioxide from fossil fuel use is trapping extra heat.

Standards Alignment:

HS-ESS3-3 Management of natural resources

HS-ETS1-1 Analyze a major global challenge

WHST.9-12.7 Conduct short research project to answer a self-generated question

HSN-Q.A.3 Choose a level of accuracy appropriate to limitations on measurement

Disciplinary Core Ideas:

ESS3.D Human Impacts on Earth Systems

ETS1.A Defining and Delimiting an Engineering Problem



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How To Use These Activities:



Pages with the circular “TILclimate Guide for Educators” logo are intended for educators. Simpler pages without the dark band across the top are meant for students.

Each of the included activities is designed to be used as a standalone, in sequence, or integrated within other curriculum needs. A detailed table of contents, on the next page, explains what students will do in each activity.

A Note About Printing/Materials

All student pages are designed to be printable in grayscale, except for the optional example wind map on page 8. A few copies of this page could be printed color for students to share, or the image projected in the classroom.

The worksheets do not leave space for students to answer questions. Students may answer these questions in whatever form is the norm for your classroom – a notebook, online form, or something else. This allows you, the teacher, to define what you consider a complete answer.

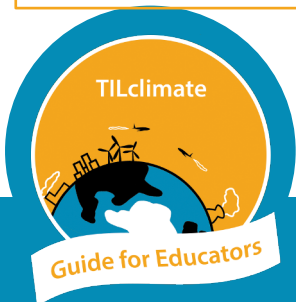
Answers to “The Story of...” Pages

Oil: H, F, B, C, A, I, E, D, J, G

Coal: G, E, C, A, H, D, B, I, F

Podcasts in the Classroom: Throughout these Guides for Educators, we invite students to think about how they would share their learning with family and friends. One way to do this is to encourage your students to create their own podcasts - they're shareable, creative, and have multiple options for embedded assessment. We would love to hear any podcasts or see any other projects you or your students create! Email us at tilclimate@mit.edu, Tweet us @tilclimate, or tag us on Facebook @climateMIT.

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Detailed Table of Contents

Page	Title	Description	Time (min)
	Podcast Episode	Students listen to TILclimate: TIL about fossil fuels, either as pre-class work at home or in the classroom. https://climate.mit.edu/podcasts/e2-til-about-fossil-fuels	10-15
1-4	The Story of Fossil Fuels	Students are introduced to various fossil fuels, and then rearrange the scrambled steps of the formation of oil & gas and coal.	10-20
5-6	Asking SMART Questions	Reading: Students are introduced to the SMART metric for designing testable, answerable questions.	5-10
7-8	SMART Question Example: Wind Power	Whole-class walkthrough: A step-by-step example developing and answering a SMART question based on the EIA's Wind Energy map.	10-15
9-10	Fossil Fuels: SMART Questions (internet required)	Using interactive maps from the Energy Information Administration, students design and answer their own SMART question about fossil fuels in the United States.	20-45+
11	SMART Question Rubric	A rubric for student or educator use to evaluate student questions before attempting to answer them.	n/a



Today I Learned About Fossil Fuels

Season 2 Collection

Season 2 of TILclimate from MIT covers a series of interrelated energy subjects. The associated teacher guides are structured for maximum flexibility. Each episode's activities could be done as a whole class or as small-group work while other teams work on other topics and share back in a jigsaw. Some activities also can be enrichment or homework, and many as asynchronous assignments for remote work. Activities of similar length could also be set up as rotating stations, with a group discussion at the end of class.

- Introductory activities are quick (15-25 minutes) and require no internet.
- Dive Deeper activities are longer (30-60 minutes) and require internet access.

The City of the Future overall project is flexible in terms of time, space, and materials. It will be engaging whether students have completed all activities in the collection, or just one. If teams of students have been working on one topic each, the City of the Future process will help them share their learning with the rest of the class.

Fossil Fuels

This Educator Guide includes the story of fossil fuels and a process to develop testable questions. Educators may pick and choose among the pieces of the Guide, as suits their class needs.

Parts of this Guide may align with the following topics:

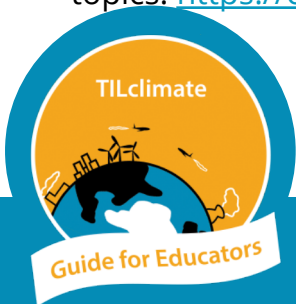
- Physical science: Distribution of natural resources
- Life/environmental science: Impacts of fossil fuel extraction, distribution, and use. Geologic history.
- History/social science: Policies regarding fossil fuels and other energy sources.
- ELA/literature: Connections to fictional works about fossil fuel extraction (coal mining, etc.) or future climate impacts.
- ELA/nonfiction: Clarifying and answering complex questions. Research methods.

MIT Resources

We recommend the following as resources for your own better understanding of climate change or as depth for student investigations. Specific sections are listed below:

- Climate Science, Risk & Solutions, an interactive introduction to the basics of climate change. <https://climateprimer.mit.edu/>
Chapter 02 The greenhouse effect and us
Chapter 10 What can we do?
- MIT Climate Portal Explainers are one-page articles describing a variety of climate topics. <https://climate.mit.edu/explainers>

Mining and Metals
Greenhouse Gases
Carbon Pricing



Today I Learned About Fossil Fuels

Wrap-Up Discussion Questions

- Why are fossil fuels considered non-renewable?
- Why are they called fossil fuels?
- What is the relationship between fossil fuels and climate change?
- What questions did you have while exploring the EIA website?
- What questions do you still have?
- What questions could you answer using the EIA website? What other information would you still need to answer your questions?

Climate Solutions

Climate solutions can be thought of as falling into four categories outlined below. Across all categories, solutions at the community, state or federal level are generally more impactful than individual actions. For example, policies that increase the nuclear, solar and wind mix in the electric grid are generally more effective at reducing climate pollution than asking homeowners to install solar panels. For more on talking about climate change in the classroom, see “How to Use This Guide”.

•Energy Shift

How do decision-makers make the switch from carbon-producing energy to carbon-neutral and carbon-negative energy?

•Energy Efficiency

What products and technologies exist to increase energy efficiency, especially in heating and cooling buildings?

•Adaptation

How can cities and towns adapt to the impacts of climate change?

•Talk About It

Talking about climate change with friends and family can feel overwhelming. What is one thing you have learned that you could share to start a conversation?

What solutions are the most exciting in your classes? We would love to hear from you or your students! Images, video, or audio of student projects or questions are always welcome. Email us at tilclimate@mit.edu, Tweet us @tilclimate, or tag us on Facebook @climateMIT.



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 (CO₂) 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 CO₂ 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.

Images from The Noun Project by Smalllike, Amethyst Studio, BomSymbols, WebTechOps, and Adrien Coquet.

Today I Learned About Fossil Fuels

Fossils?



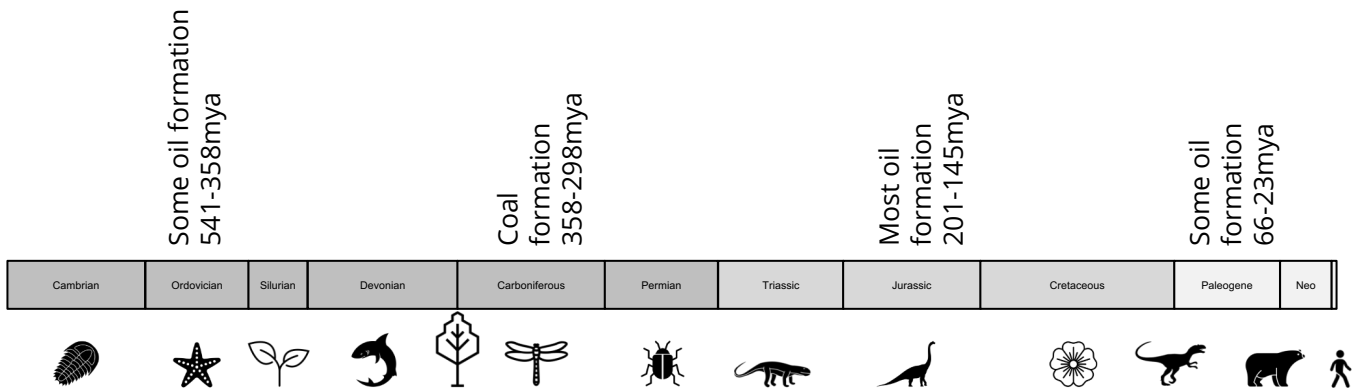
When most people hear the phrase “fossil fuels” their first thought probably has more to do with dinosaurs than with coal, oil, and natural gas. In fact, people sometimes call petroleum products “dinosaur juice.” But do fossil fuels actually come from dinosaurs? How did that oil get underground? And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

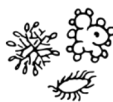
Images from The Noun Project by Charlotte Vogel, Guilherme Furtado, Xing Studio, Andi, Phạm Thanh Lộc, Aitor, Harold Weaver, Adrien Coquet, CombineDesign, and Firza Alamsyah
Oil formation estimates from https://energyeducation.ca/encyclopedia/Oil_formation

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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.



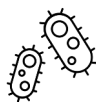
C. Diagenesis Over millions of years, sediment layers grow, adding pressure to the decomposed organic matter and increasing the temperature. This forms two new substances, kerogen and bitumen.



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."



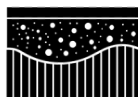
F. Growth Algae and plants in the ocean grow, converting the glucose to the proteins, carbohydrates, lipids, and lignin that they need to live. Other organisms create more of these compounds when they eat the algae and plants.



G. Impact As we burn fossil fuels like oil and natural gas, we release the carbon dioxide from photosynthesis millions of years ago. This CO₂ 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 (CO₂) and water (H₂O) to form glucose (C₆H₁₂O₆), oxygen (O₂), 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 ($\text{C}_6\text{H}_{12}\text{O}_6$), 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?”

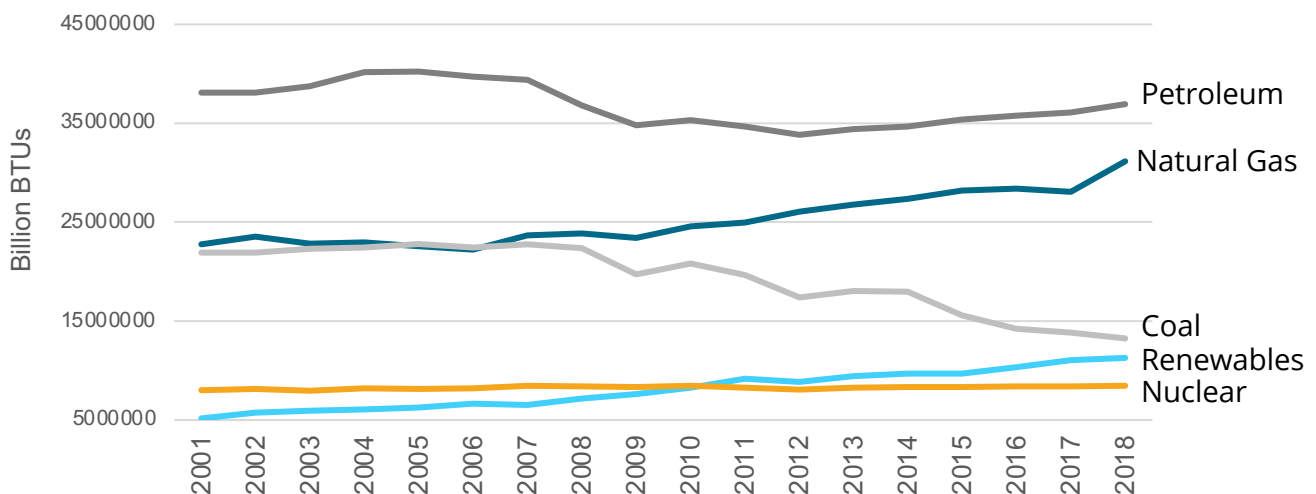
*Dr. John Reilly, MIT Joint Program of Science and Policy of Global Change
TILclimate podcast: Today I Learned About Fossil Fuels*

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 (CO₂) into the atmosphere. Carbon dioxide acts like a blanket, trapping heat from the sun. A regular amount of CO₂ in the atmosphere is needed for life on Earth, but the excess CO₂ 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



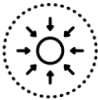




Data from the US Energy Information Administration <https://www.eia.gov/beta/states/data/dashboard/consumption>.

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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?

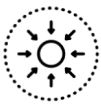
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SMART Question Example

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?

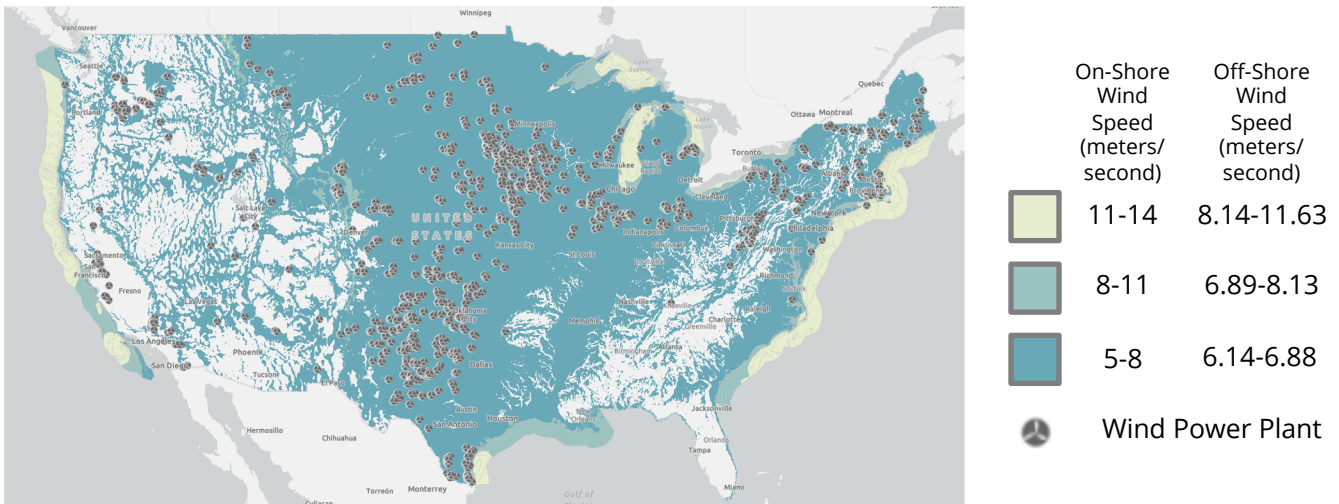
- Time could mean within a year (variations in weather, energy use, etc. over a year) or it could refer to the data collection (when was this dataset updated?) In this case, if the wind power plant locations were not up-to-date, it might change our answer.

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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.)



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?






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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*

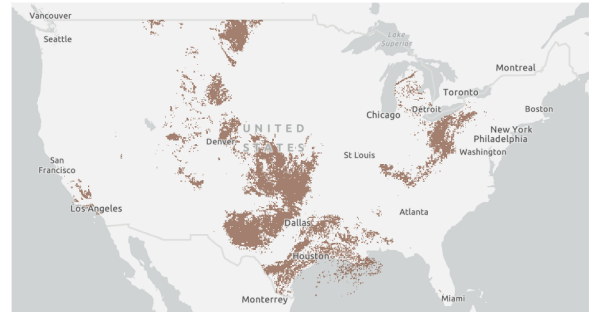
Explore the Tools

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.



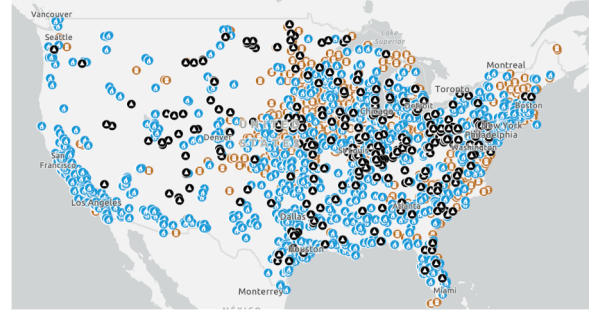
Natural Gas Wells



Oil Wells



Coal Mines



Fossil Fuel Power Plants

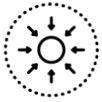
All images from the US Energy Information Administration <https://atlas.eia.gov/apps/fossil-fuels/explore>

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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.