

Today I Learned About Nuclear Power

Description:

The use of nuclear power is controversial in some places, and commonplace in others. How do we estimate risk when making choices about how to generate energy? What are the effects of those choices? Through a series of activities, students learn about risk perception and investigate real data about the intersection of energy use, energy production, and carbon dioxide emissions around the world.

Skills & Objectives

SWBAT

- Explain what risk perception is.
- Explain which energy sources carry the highest risk for fatalities and emissions.
- Understand that different countries have made choices about the use of nuclear and other energy sources. Those choices have affected carbon dioxide emissions and other factors in each of those countries.

Skills

- Prediction
- Reading and interpreting graphs
- Communication

Students Should Already Know That

- Various energy sources come with different emissions and pollution profiles.

Standards Alignment:

HS-ETS1-1 Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions

HS-ETS1-3 Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs

RST.11-12.7 Integrate and evaluate multiple sources of information presented in diverse formats and media

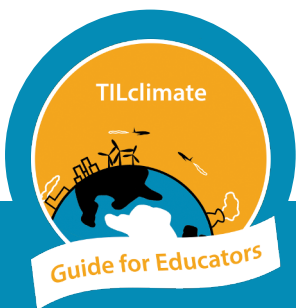
RST.11-12.9 Synthesize information from a range of sources into a coherent understanding of a process, phenomenon, or concept

HSS-IC.B.6 Evaluate reports based on data.

Disciplinary Core Ideas:

ESS3.C Human Impacts on Earth Systems

ESS3.D Global Climate Change



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How To Use These Activities:



Pages with the circular “TILclimate Guide for Educators” logo and dark band across the top 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.

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.

Social-Emotional Learning

Both risk-assessment activities have the potential to be challenging conversations, as they deal with accidental death. Consider how to frame either activity with your students to support social-emotional and trauma-informed learning. For more on discussing difficult issues in the classroom, consult the “How to use TILclimate Educator Guides” document that can be found on the same website where you found this Guide, or at <https://climate.mit.edu/sites/default/files/2021-08/How%20to%20Use%20TILclimate%20Educator%20Guides.pdf>

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.



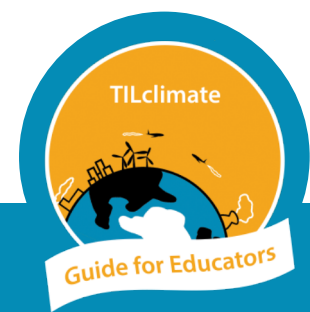
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Today I Learned About Nuclear Power

Detailed Table of Contents

Page	Title	Description	Time (min)
	Podcast Episode	Students listen to TILclimate: TIL about nuclear power, either as pre-class work at home or in the classroom. https://climate.mit.edu/podcasts/e6-til-about-nuclear-power	10-15
1	Risk Perception: Cognitive Biases	Reading: Students are introduced to three common cognitive biases that may affect risk perception.	5-10
		Choose one or the other of the following risk perception activities. See note on previous page about Social-Emotional Learning.	
2-3	Risk Perception: Emissions & Safety	Worksheet: Students read about emissions and fatalities associated with various energy production methods. Based on data, they consider which forms of energy are the riskiest.	15-20
4-5	Risk Perception: Odds of Fatality	Worksheet: Students rank their perception of the risk of fatality associated with various non-medical activities, and then consider real data and how their perception of risk may have formed.	15-20
6-9	Nuclear Power: Global Choices (internet required)	Students investigate the energy use, energy mix, and CO ₂ emissions of one of five countries around the world. Then, in teams, they compare the five countries and discuss how these factors influence one another and how countries make energy choices. Alternatively, each student could investigate two countries and write an essay comparing and contrasting them.	30-45+



Today I Learned About Nuclear Power

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.

Nuclear Power

This Educator Guide includes readings, worksheets, and data investigation. 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: Nuclear fusion, energy production and use.
- Life/environmental science: Climate change, international climate agreements.
- History/social science: History of nuclear use, international agreements.
- ELA/literature: Fictional texts related to nuclear use.
- ELA/nonfiction: Comparing and contrasting technical data.

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 07 Understanding risk
 - 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>
 - Nuclear Energy
 - Greenhouse Gases



Today I Learned About Nuclear Power

Wrap-Up Discussion Questions

- Which cognitive biases do you think affected your risk perception?
- When local, state, and federal leaders are making decisions about how to produce energy, what factors do you think they include?
- Why is it important to use 'per capita' data when comparing countries?
- What is the relationship between per capita energy use, energy mix, and carbon dioxide emissions?
- Based on what you have seen so far, what do you predict will happen with energy mix, energy use, and CO₂ emissions in each of these countries over the next 20 years?
- What other questions do you have about nuclear power? How would you investigate these 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?

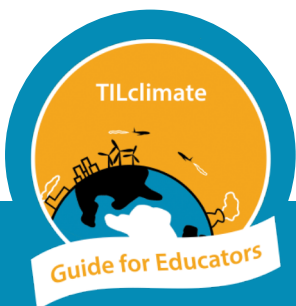
• Adaptation

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.



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"The main concern that I think people have is associated with fairly spectacular, rare events - accidents."

Prof. Jacopo Boungiorno MIT nuclear science and engineering

TILclimate podcast: Today I Learned About Nuclear Power

Risk Perception Biases

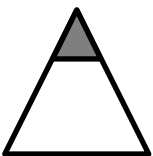
Every day, we make choices that include risks. We make choices about getting around, eating, living arrangements, and everything else. The risks we choose each day range from major (whether to run across a busy road) to minor (whether to carry a near-overflowing glass of milk). While we may make lists and thoughtfully consider big decisions, we would be easily overwhelmed if we had to calculate the risks of every daily choice.

Scientists who study the human brain have found that we have certain *cognitive biases* when it comes to weighing risk. These are shortcuts our brain uses to help us with the thousands of decisions we must make each day. Here is a short list of cognitive biases that may affect our ability to make decisions about risk:



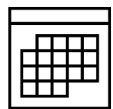
Anchoring bias: We tend to rely heavily on the first piece of information we are given about a topic, especially if it is a number. When we get new information, we think of it as it relates to that first impression.

Example: An item is listed as costing \$50, with a discount to \$30. People are more likely to buy it with the discount than if the price was simply \$30. The \$50 price tag *anchors* their sense of the item's value.



Survivorship bias: We tend to focus on and hear about the people or groups who have succeeded in or survived something, rather than those who have not.

Example: Media representations remember and celebrate the few start-up companies that have *survived* and done well, while ignoring the thousands that have failed. We are likely to think that start-up companies do well in general.



Availability bias: We are more likely to remember the most recent stories we have heard related to a choice.

Example: People avoid the beach after reports of shark incidents – even when the shark incident was in a different state than the beach they are visiting. The story is more *available* to their minds than the fact that they have never seen a shark.

We like to believe that we make all our decisions based on logic, information, and rational thought. In practice, cognitive biases tend to outweigh numbers and statistics.

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“When it comes to risk and public health impact, there is no way to be particularly cheerful or positive, you have to look at the hard cold numbers and compare.”

*Prof. Jacopo Boungiorno MIT nuclear science and engineering
TILclimate podcast: Today I Learned About Nuclear Power*

What are the safest sources of energy?

When asked whether they support the expansion of nuclear power, many people point to large-scale nuclear disasters like Chernobyl and Fukushima. Is nuclear power more dangerous than other forms of energy? For this exercise, we will focus on two measures of safety: emissions and fatalities (deaths.)

Emissions: We know that carbon dioxide (CO₂) in Earth’s atmosphere acts like a heat-trapping blanket. We need some blanket around Earth to maintain life, but too much means that we are warming our Earth, ocean, and air. This warming is causing dramatic changes in climate and weather patterns.

- To simplify emissions data, scientists calculate the warming effects of all the greenhouse gases (CO₂, methane [CH₄] and others) and use its "carbon dioxide equivalent" or "CO₂e" -- how much CO₂ would create that same amount of warming.
- Emissions may come directly from the burning of fuels, or during the fabrication, construction, transportation, mining, or extraction process.
- The data here are in CO₂e per gigawatt-hour of electricity, to make comparisons fair among more- and less-common electricity sources.

Fatalities: Any industry or process has a ‘mortality rate,’ or the number of people worldwide who die each year associated with that activity. Some industries or processes are much more dangerous than others.

- Air pollution causes millions of illnesses and fatalities per year. Energy sources that release larger amounts of CO₂ (coal, oil, natural gas, and biomass) also release more air pollutants, like carbon monoxide (CO), lead (Pb), and others.
- Accidents happen during the mining or extraction of a resource, during transportation of the resource, during construction of a power plant or other necessary infrastructure, or during operation of the power plant.
- The data here are in fatalities per terawatt-hour of energy production, to make comparisons fair among more- and less-common electricity sources.

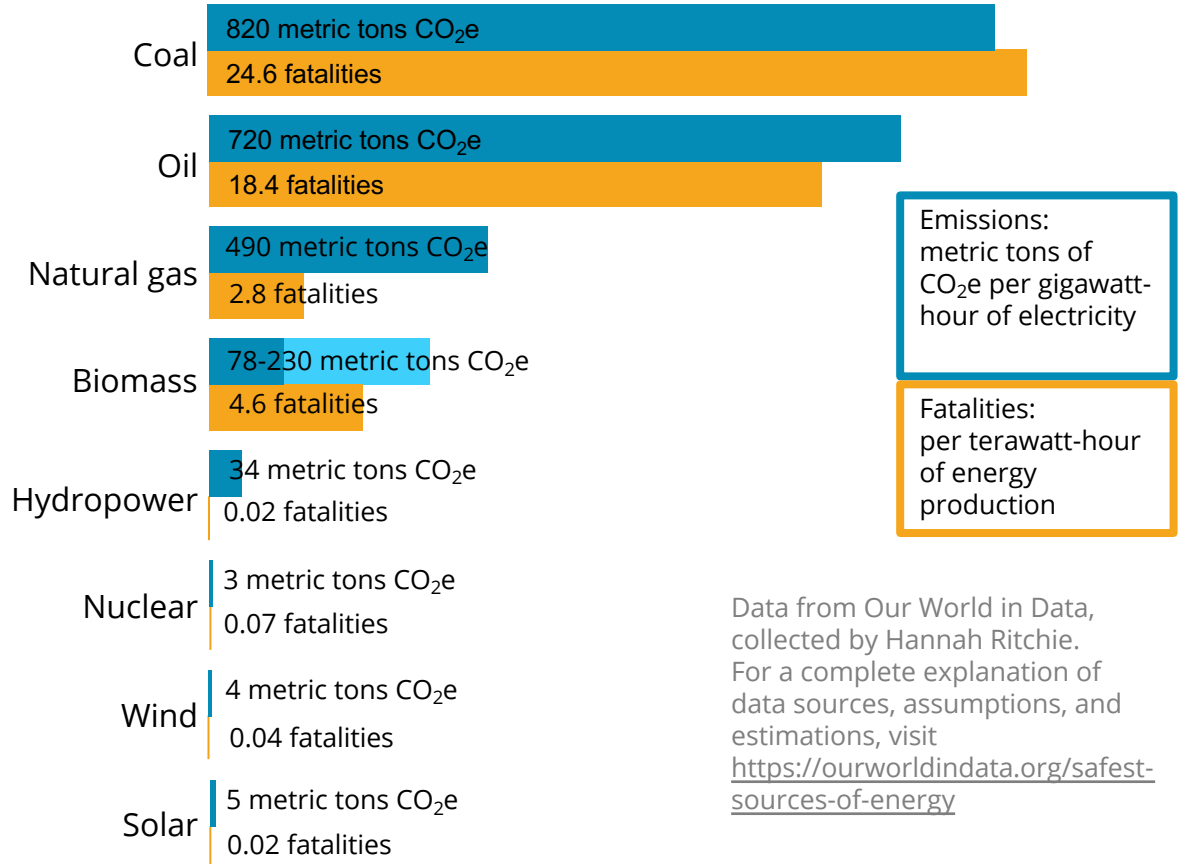
What Do You Predict?

1. Rank the following energy sources in terms of how much CO₂e you think they release, and how many fatalities you think they might cause. You do not need to be precise – just put them in order from highest to lowest in each case.

Biomass Coal Hydropower Natural Gas Nuclear Energy Oil Solar Wind

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Emissions & Safety Data



Questions

1. Look back at your prediction from the previous page. How close were you? Why?
2. What surprises you?
3. When local, state, and federal leaders are making decisions about how to produce energy, what factors do you think they include?
4. Are emissions and fatalities the only data we should investigate? What other information would you need if you were making these decisions?
5. Coal, oil, biomass, and nuclear power all produce considerable waste after they are used to produce electricity or heat. How should the environmental and health impacts of these waste products factor into decisions?
6. Around the world, energy is produced from a combination of all eight sources listed. As of 2020, coal produced 25% of the world's energy, oil 31%, natural gas 23%, biomass 7%, hydropower 6%, nuclear energy 4%, wind 2%, and solar 1%. By 2040, how do you expect these numbers to change?

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Relative Risk



Below, find ten possible causes of accidental death. Read the list and decide which are the most likely and the least likely to happen in one year. Rank all ten risks, with 1 being the activity you think causes the most fatal accidents per year, and 10 being the fewest fatalities.

Then, collect the rankings from your whole class. Calculate the average (mean) rank, as well as the range of ranks (the highest and lowest rank given in the class for that risk.)

Risk of Fatality	Your Ranking 1 = highest risk per year	Class Ranking	
		average	range
Airplane travel (commercial and private)			
Bicycle riding			
Boat travel (commercial and private)			
Electrocution			
Falling (falls on one level, on stairs, etc.)			
Fire & Smoke (building fires, etc.)			
Forces of nature (lightning, cold, heat, storms)			
Motor vehicles (cars, trucks, buses, motorcycles, etc.)			
Nuclear radiation			
Venomous animals (snakes, spiders, wasps, etc.)			

Questions

1. Which activities did your class rate as the riskiest?
2. For which activities was there the widest range of opinions? Why do you think this is?
3. What factors do you think affected your own rankings? The rankings of your classmates?

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Actual Risk

For each activity below, find the actual number of US residents who died due to that activity in 2019, as well as the calculated risk of that activity (US population divided by number of fatalities.) Numbers have been rounded to the nearest 10.

Risk of Fatality	Total fatalities, 2019	One-year risk
Falling (including falls on one level, on stairs, etc.)	39,440	1 : 8,320
Motor vehicle (including cars, trucks, motorcycles, buses, etc.)	39,110	1 : 8,390
Fire & smoke (including building fires, etc.)	2,690	1 : 121,930
Forces of nature (including heat, cold, lightning, storms, etc.)	1,810	1 : 181,750
Bicycle riding	1,090	1 : 301,410
Boat travel (commercial and private)	490	1 : 669,880
Airplane travel (commercial and private)	440	1 : 744,310
Electrocution	300	1 : 1,108,920
Venomous animals (including snakes, spiders, wasps, etc.)	110	1 : 3,126,090
Nuclear radiation	0	Cannot be calculated

Questions

1. What surprises you?
2. Where were you the most accurate? The farthest off?
3. What factors do you think affected your rankings? Those of your classmates?
4. Because you ranked these activities but did not give exact values, you are likely to think of them as equally distributed along a line. Create a graph to see the relative rates for the various activities. (Total fatalities due to accidental injuries in 2019 were 173,040.)

Source: National Center for Health Statistics.--Mortality Data for 2018 as compiled from data provided by the 57 vital statistics jurisdictions through the Vital Statistics Cooperative Program.

<https://injuryfacts.nsc.org/all-injuries/preventable-death-overview/odds-of-dying/data-details>

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"You have an energy source that essentially does not have any emissions into the atmosphere and so that's the first reason why people are interested in nuclear now; because of course we're trying to minimize the carbon emissions into the atmosphere to prevent massive global warming and climate change."

Prof. Jacopo Boungiorno MIT nuclear science and engineering

TILclimate podcast: Today I Learned About Nuclear Power

Global Choices

In most countries, most of the energy used comes from the burning of fossil fuels like coal, oil, and natural gas. When we burn these fuels, we release carbon dioxide (CO₂) into the atmosphere. Carbon dioxide and other gases act like a blanket, trapping heat on Earth. This trapped heat is changing our climate, causing dramatic changes in extreme weather and other effects all over the world.

Each country is making its own choices about how to generate energy for its residents. Some are including nuclear heavily in their energy portfolios, while others are reducing the number of nuclear reactors they use. How do these choices affect the other energy sources these countries use, and ultimately their emissions?

Five Countries: A Snapshot

One way to see the choices that a country is making about the use of nuclear is to look at how many nuclear reactors they have operational, permanently shut down, and under construction. The "Nuclear Share" is a measure of the percentage of energy in the country produced from nuclear power. As of 2020, the International Atomic Energy Agency listed the following:

Country	Operational	Shut Down	Construction	Nuclear Share 2001	Nuclear Share 2020
France	56	14	1	77%	71%
Japan	33	27	2	34%	5%
South Korea	24	2	4	39%	30%
United Kingdom	15	30	2	23%	15%
Germany	6	30	0	30%	11%

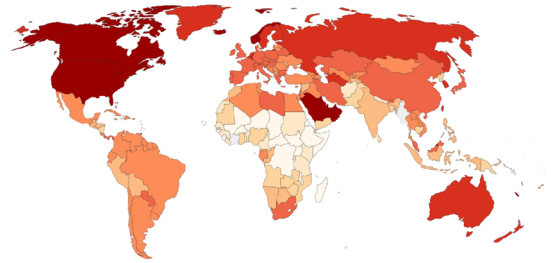
How would you characterize each of the country's use of nuclear power?
(Consider both trends over time and whether the overall level is high, medium, or low.)

Data from the International Atomic Energy Agency's Power Reactor Information System <https://pris.iaea.org/PRIS/>

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Energy use per person

OurWorld
in Data



Source: Our World in Data based on BP & Shift Data Portal

Note: Energy refers to primary energy – the energy input before the transformation to forms of energy for end-use (such as electricity or petrol for transport).

OurWorldInData.org/energy • CC BY

Energy Mix & Consumption

1. Visit <https://ourworldindata.org/energy#energy-country-profiles> and search for one of the five countries from the previous page.
2. Scroll down to the “Energy and electricity consumption” section of the page. The first graph in this section shows total energy use per person over time.

Observe Describe what you see in this graph. How has per capita energy use changed over time? What has been the trend in the recent past?

3. Scroll down to the “Energy mix” section of the page. The second graph in this section is titled “Share of energy consumption by source.” This shows the percentage of overall energy use from each source over time.

Observe Describe what you see in this graph. Which energy sources have changed their overall share? In which direction? (If you hover your mouse over the name of an energy source, it will highlight that source and gray out the others.)

Analyze The next few graphs in this section give greater depth to the observations you made with the first graph. What do you notice? What questions do you have?

4. Choose one “per capita” graph of interest on this page. In the upper left corner, click “Add Country” and add the data of another country.

Observe What do you notice among these two countries? Why is it important to compare ‘per capita’ data?

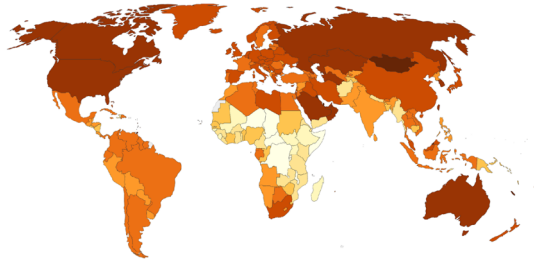
Extend What other questions do you have about this country’s energy use? How could you answer those questions?

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Per capita CO₂ emissions

Carbon dioxide (CO₂) emissions from the burning of fossil fuels for energy and cement production. Land use change is not included.

Our World
in Data



No data 0 t 0.1 t 0.2 t 0.5 t 1 t 2 t 5 t 10 t 20 t >50 t

Source: Our World in Data based on the Global Carbon Project [OurWorldinData.org/co2-and-other-greenhouse-gas-emissions/](https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions/) • CC BY
Note: CO₂ emissions are measured on a production basis, meaning they do not correct for emissions embedded in traded goods.

CO₂ Emissions

5. Visit <https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions> and search for the same country as before. (You may want to do this in a new tab.)
6. Scroll down to the “CO₂ emissions” section of the page. The first graph shows how much CO₂ is emitted per person over time. (Please note that this graph may go back much further in time than the energy profile graphs.)

Observe Describe what you see in this graph. What has the trend in CO₂ emissions per capita been over the past few decades?

7. Scroll down to the “Coal, oil, gas, cement” section of the page. The second graph shows CO₂ emissions by type of fuel over time. (If you hover your mouse over the name of an energy source, it will highlight that source and gray out the others.)

Observe Describe what you see in this graph. What has the trend in CO₂ emissions per capita been over the past few decades?

8. Choose one “per capita” graph of interest on this page. In the upper left corner, click “Add Country” and add the data of another country.

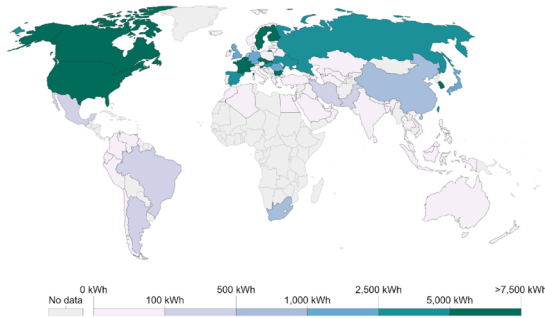
Observe What do you notice among these two countries? Why is it important to compare ‘per capita’ data?

Extend What other questions do you have about this country’s emissions? How could you answer those questions?

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Per capita energy consumption from nuclear
Energy consumption is based on primary energy equivalents, rather than final electricity use.

Our World
in Data



Source: Our World in Data based on BP Statistical Review of World Energy & UN Population Division. OurWorldinData.org/energy - CC BY
Note: "Primary energy" refers to energy in its raw form, before conversion into electricity, heat or transport fuels. It is here measured in terms of "input equivalents" via the substitution method: the amount of primary energy that would be required from fossil fuels to generate the same amount of electricity from nuclear.

Putting It All Together

1. How have changes in energy mix and per capita energy consumption affected CO₂ emissions in this country over time?
2. Do you think changes in nuclear power use have had a positive, negative, or neutral effect on this country's CO₂ emissions? Why?
3. Briefly describe the changes in energy mix, energy consumption, and CO₂ emissions.
4. Form groups with representatives who have studied each of the five countries. Share what you have learned with your group.

Discuss

- Are there any patterns among these countries?
- Based on what you have seen so far, what do you predict will happen with energy mix, energy use, and CO₂ emissions in each of these countries over the next 20 years?
- If you were advising the leaders of the country you studied, what would you advise they do with their energy mix?
- What other information would you need to give the best advice?
- Why do you think these countries have made the choices they have?

Share

- Have you learned anything surprising through this activity? Who would you like to share your new understandings with?
- Talking about big issues like climate change and nuclear power can seem overwhelming. Remember that you do not need to be an expert. What piece of information did you learn that you found the most interesting? Share that information and see where the conversation goes.