Today I Learned About Nuclear Power

"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

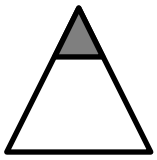
Risk Perception Biases

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:

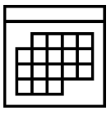
Anchoring bias: We tend to rely heavily on the first piece of information we are given about a topic, especially if it is a number. When we get new information, we think of it as it relates to that first impression.

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."

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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 (CO_2) 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 (CO_2, methane [CH_4] and others) and use its "carbon dioxide equivalent" or "CO_2e" -- how much CO_2 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 CO_2e 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 CO_2 (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 CO_2e 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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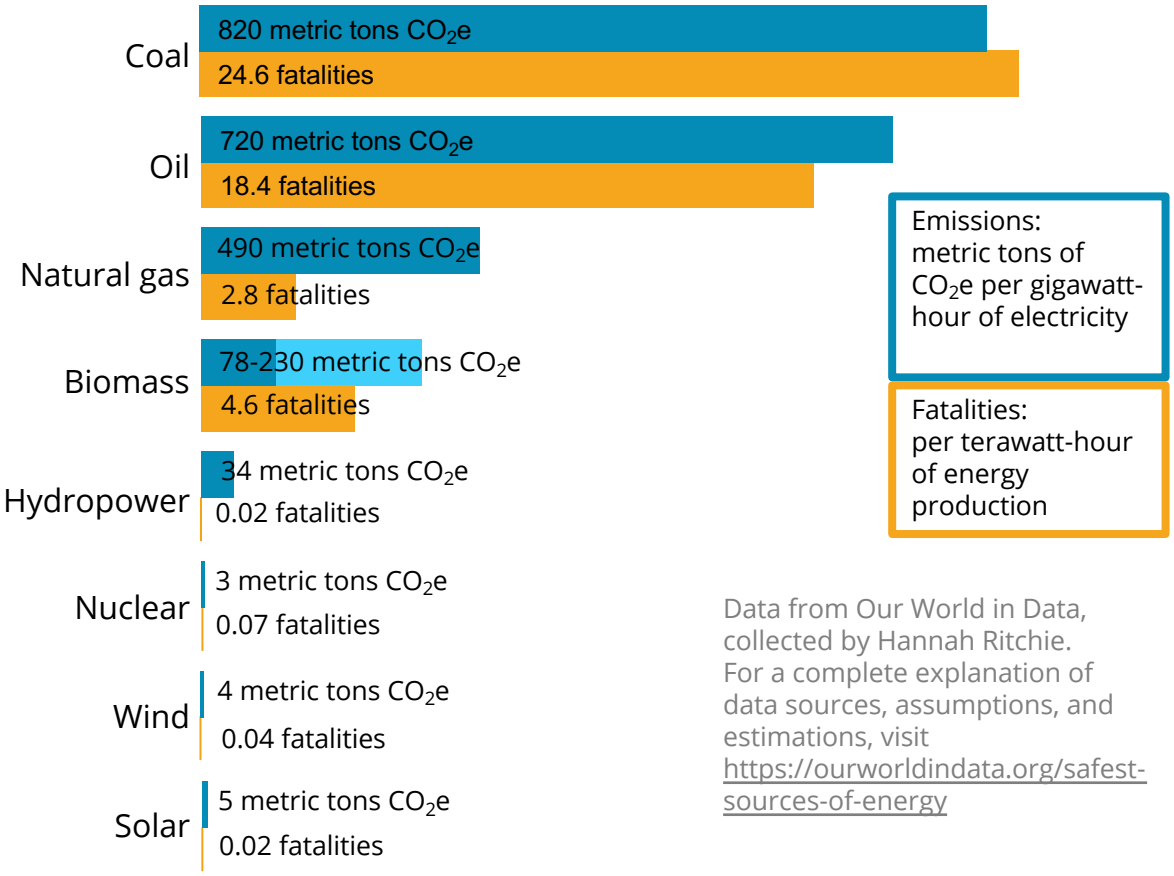
Emissions & Safety Data



Data from Our World in Data, collected by Hannah Ritchie.
For a complete explanation of data sources, assumptions, and estimations, visit https://ourworldindata.org/safest-sources-of-energy

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."

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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 (CO_2) 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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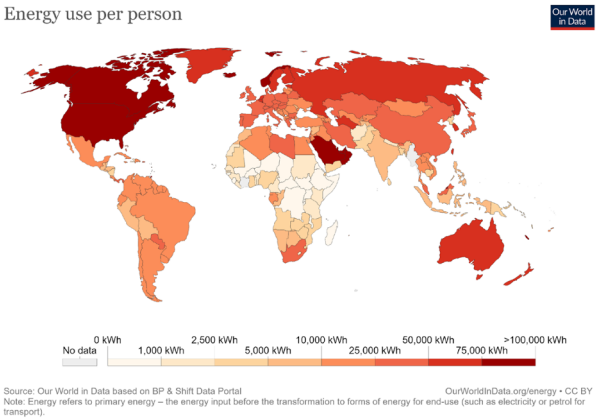

Energy Mix & Consumption

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?

Map from https://www.OurWorldInData.org/energy

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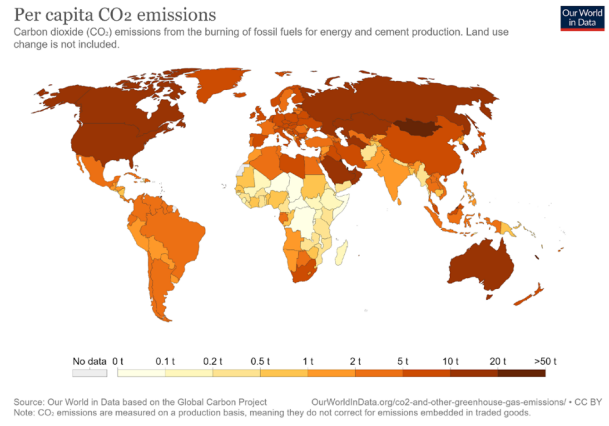

CO_2 Emissions

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 "CO_2 emissions" section of the page. The first graph shows how much CO_2 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 CO_2 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 CO_2 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 CO_2 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?

Map from https://ourworldindata.org/co2-emissions

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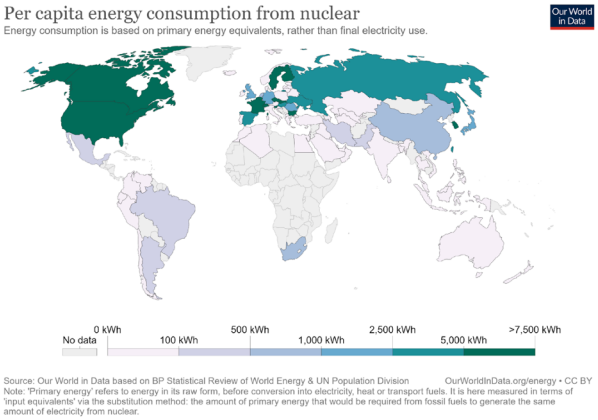

Putting It All Together

1. How have changes in energy mix and per capita energy consumption affected CO_2 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 CO_2 emissions? Why?
3. Briefly describe the changes in energy mix, energy consumption, and CO_2 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 CO_2 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.

Map from https://ourworldindata.org/grapher/per-capita-nuclear