Today I Learned About Hydrogen Energy

"If you are somewhere where you have wind or solar, you can use wind and solar and water and produce hydrogen."
Dr. Svetlana Ikonnikova, Technical University of Munich
TILclimate podcast: Today I Learned About Hydrogen Energy

Green Hydrogen

As Dr. Ikonnikova explains in the podcast episode, hydrogen gas can be produced in several different ways. Currently, most is produced by splitting a methane (CH_4) molecule, which produces H_2 (hydrogen gas) and carbon dioxide (CO_2). If this carbon dioxide is not captured, it is released into the atmosphere, where it acts like a heat-trapping blanket around Earth. This trapped heat warms Earth, dramatically changing the climate and leading to more frequent strong storms, droughts, and more.

It is also possible to generate hydrogen by splitting a water molecule using electricity from solar or wind power. This way, you get hydrogen (H_2) and oxygen (O_2) which can be used to generate electricity again later.

The best locations for this kind of energy storage are places with abundant solar or wind resources and a good source of freshwater.

Where in the World?

One of the challenges of low-carbon energy sources such as wind and solar is that the sun doesn't always shine and the wind always doesn't blow. Another is that good solar and wind resources are not evenly distributed around the world. If we have ways to store energy, then extra energy from sunny or windy days or locations can be stored for nighttime, still days, and other places.

On the following pages, find world maps that show freshwater resources, solar power potential, and wind power potential. In your groups, compare the three maps.

Observe & Discuss

Where in the world do you find medium to very high sources of freshwater and medium to high levels of either solar or wind energy?

How might this affect the usability of hydrogen to store excess energy from solar and wind power?

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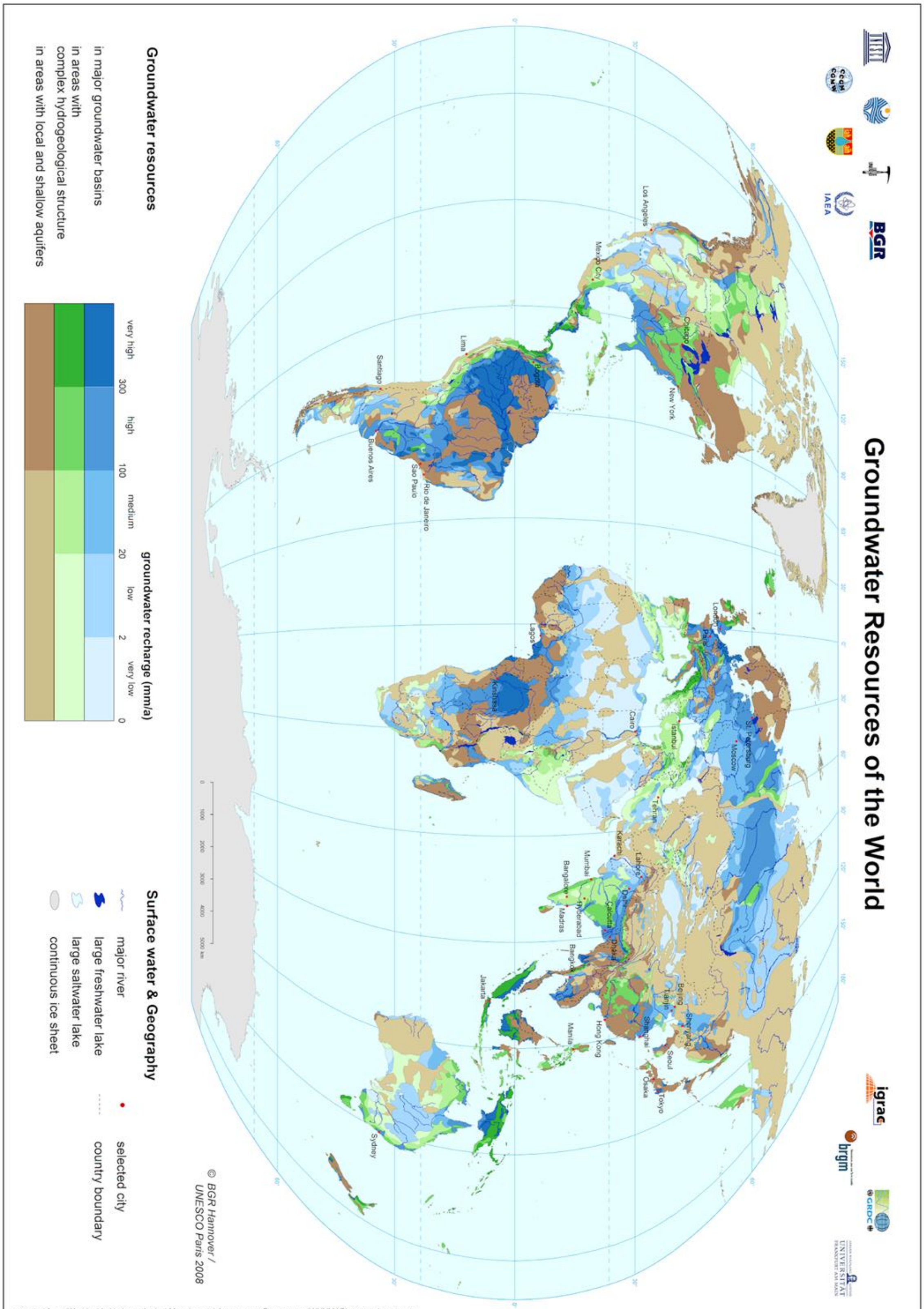

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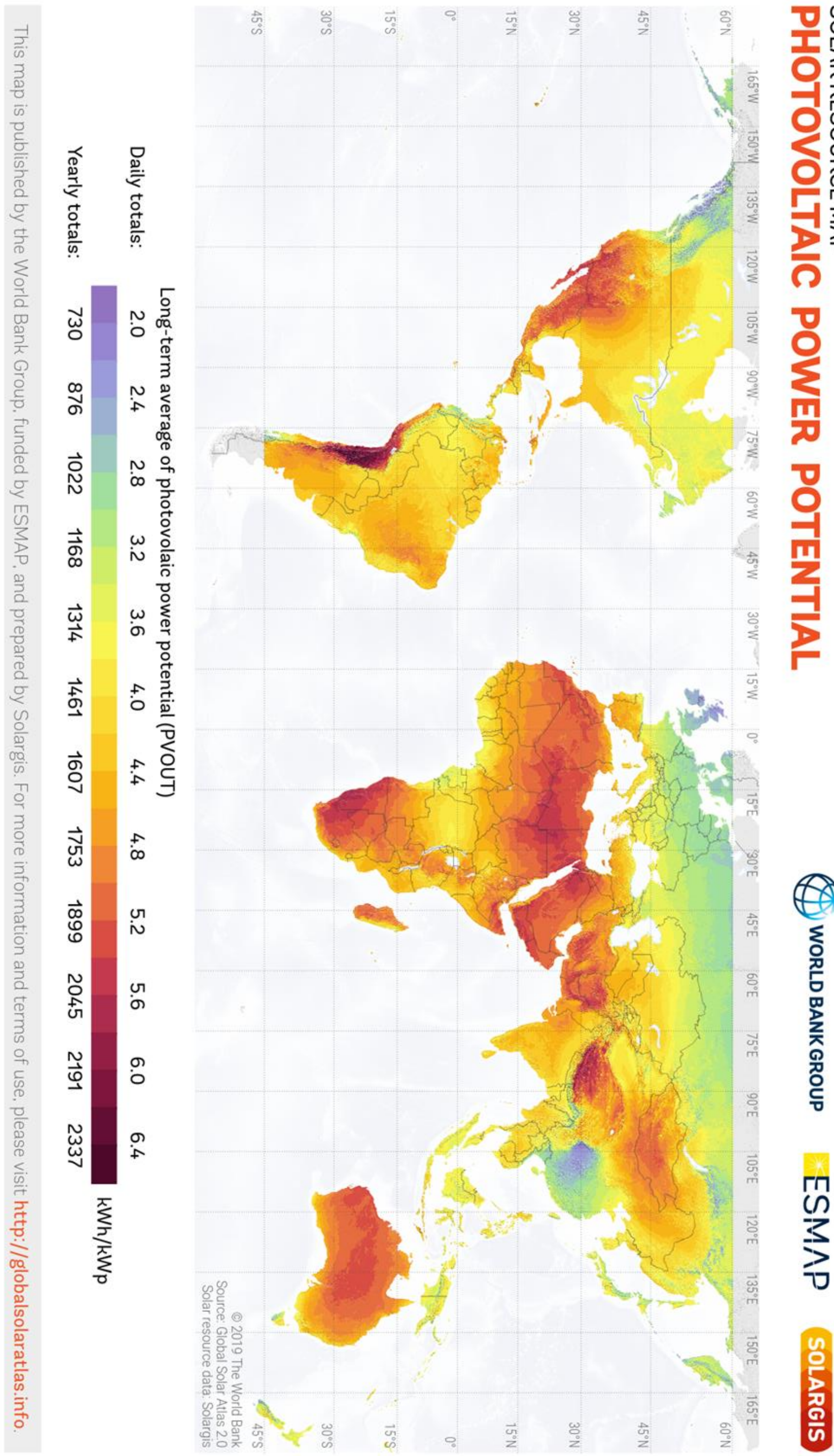

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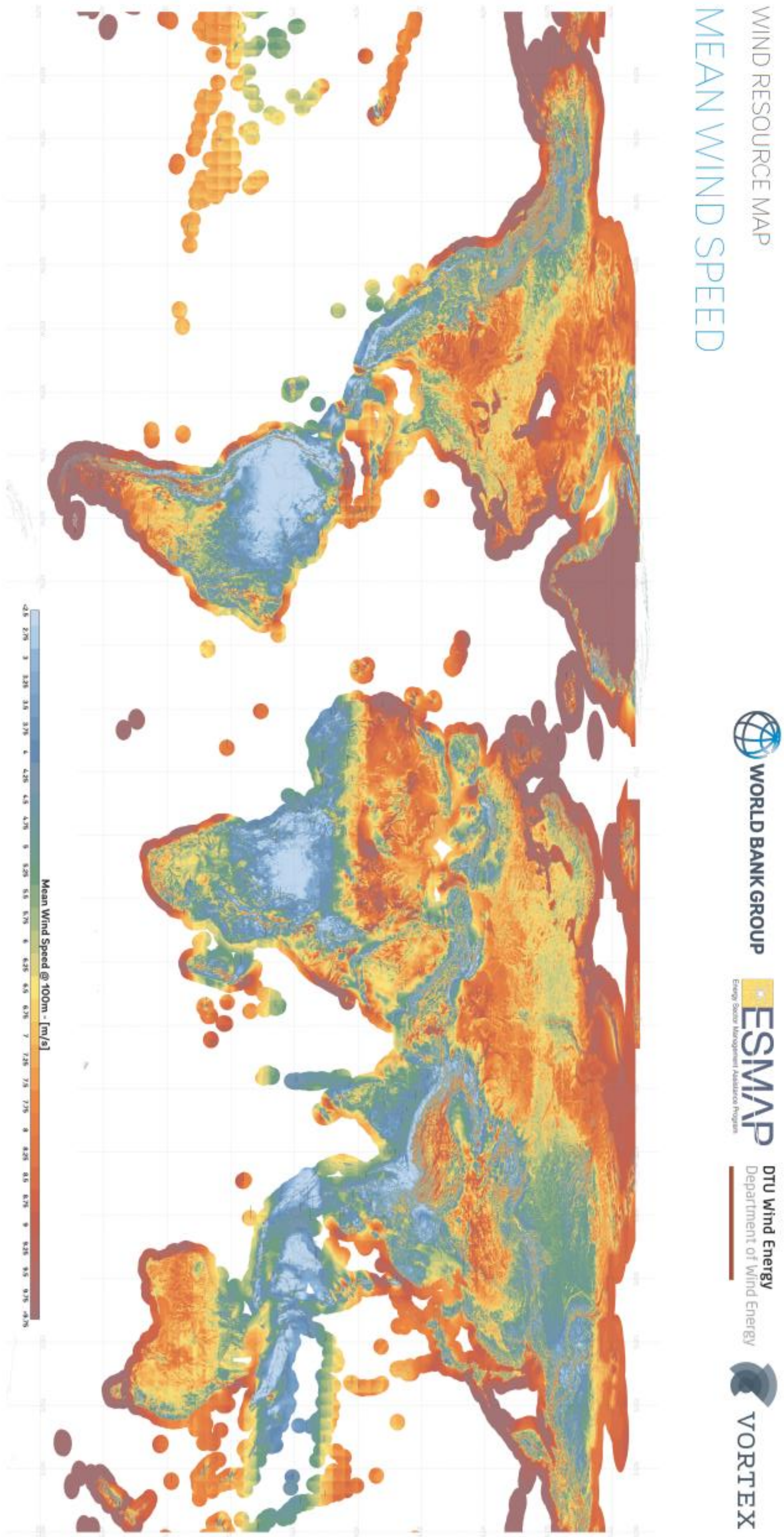

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"In the beginning of the 19th century, Sir William Grove figured out that if you apply [electricity] to water, you can split the water molecule into oxygen and hydrogen. And he got an idea that you could apply a reverse reaction in order to bring the two things back."
Dr. Svetlana Ikonnikova, Technical University of Munich
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Try It Yourself!
With a few common laboratory ingredients, you can split water into oxygen and hydrogen gases. Follow the instructions from the Exploratorium.
https://www.exploratorium.edu/snacks/having-gas-with-water

Portable Electricity

Today, we are very used to the idea that we can carry around electricity – in a form called batteries! But how does a battery work, and how is it different from a hydrogen fuel cell?

On the following pages, find a series of diagrams and descriptions of a disposable battery, rechargeable battery, fuel cell, and the process to make hydrogen gas. Read and discuss the descriptions with your group, and then come back to this page.

Represent This

Choose one of the following topics based on the diagrams you looked at:

A. Batteries vs fuel cells – what's the difference?

B. Hydrogen fuel cells – how do they work, and where does the hydrogen come from?

C. Hydrogen gas – how can we make it?

D. Design your own topic.

In your group, decide how you would like to explain this topic to someone else. You could use code, blocks, magnets, animation, illustration, video, interpretive dance… the possibilities are endless. Your goal is to help the audience of your choice understand the topic and how it relates to their life.

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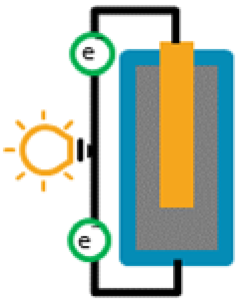
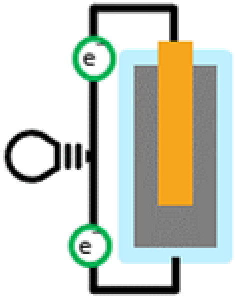
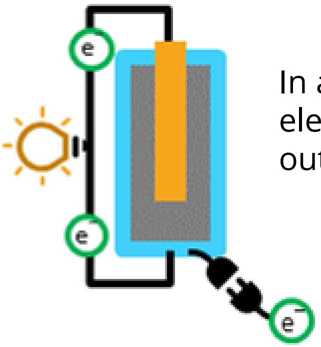
Batteries



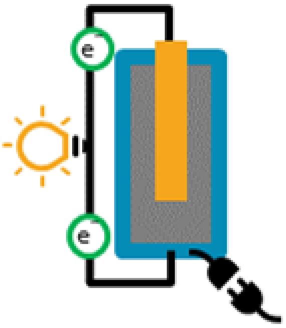
In most batteries, a metal (blue) *oxidizes*, which sends electrons (green circles) along a wire (black), generating an electrical current and lighting the lightbulb. Another metal (yellow) *reduces*, taking in the electrons. An *electrolyte* (gray) allows the electrical charge to pass between the two metals inside the battery.



When drawing electricity from the battery, the *oxidizing* metal loses electrons, and can no longer generate electrical current. In a **disposable** battery, this means it is time to replace the battery.



In a **rechargeable** battery, the process can be reversed by adding electricity from another source (such as plugging the device in to a wall outlet). This *reduces* the *oxidizing* metal (blue), so it is ready to *oxidize* again.



Each time the battery is used and recharged, the *oxidizing* metal can only recharge partway, and the battery loses charge more quickly.

For more on how batteries work, see https://ed.ted.com/lessons/why-batteries-die-adam-jacobson

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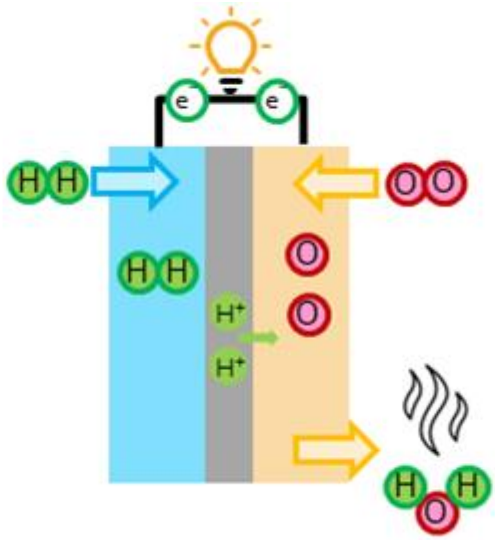
Fuel Cell

There are many types of fuel cells, using different chemistry. **Proton-exchange membrane fuel cells (PEMFCs)** are the most common in vehicles and other portable uses.



Hydrogen (H_2, green filled circles) is pumped into the fuel cell, where the *electrons* (e-, unfilled green circles) are stripped away from the H_2 to flow through a wire and generate an electrical current.

The *protons* (green H^+ circles) pass through a *membrane* (gray bar).

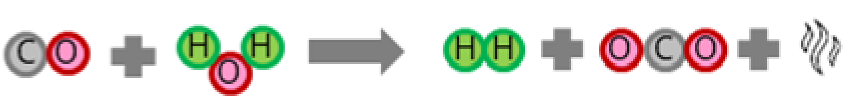
Oxygen (O_2, red circles) is pumped in from the air on the other side of the membrane.

The *protons*, *electrons,* and oxygen atoms combine to form water vapor (H_2O) and heat.

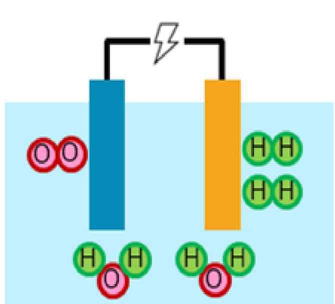
How Do You Make Hydrogen?

Hydrogen is found in many molecules. Most hydrogen gas is produced from the methane (CH_4) in natural gas.

Methane (CH_4) and steam (H_2O and heat) are placed under pressure to form hydrogen gas (H_2) and carbon monoxide (CO).



The carbon monoxide is then reacted with more steam to form more hydrogen gas, carbon dioxide (CO_2), and heat.



Hydrogen can also be formed from water with the addition of electricity (for example, from a renewable resource such as solar or wind power).

An electrical current passes between two poles, which are both partially submerged in water. This splits the water molecule (H_2O) and the atoms reform into hydrogen gas (H_2) and oxygen gas (O_2), which bubble out.

Energy and heat icons from The Noun Project by Teewara soontorn, Vectorstall, and IconPai

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"Hydrogen is so versatile that we can really try to substitute it across all the main sectors [where] we usually talk about CO_2 or any other greenhouse gas emissions. "

Dr. Svetlana Ikonnikova, Technical University of Munich

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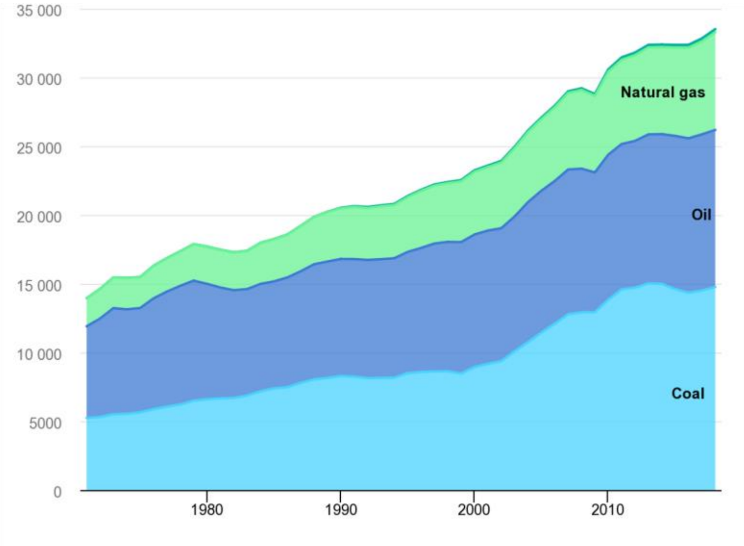

World CO2 emissions from fuel combustion, by fuel, 1971-2018, Mt[1]

World Energy Use

Each year, the world uses the equivalent of almost 10 billion tonnes of oil[1] to produce electricity, move cars and trucks around, heat our homes, and run our industries. Energy from all sources, including fossil fuels and low-carbon sources, is converted to "oil equivalents" to make it easier to compare them. About 10% of this energy comes from sources that produce little to no carbon dioxide, such as solar, wind, hydropower, and nuclear. More than 80% is generated by the burning of fossil fuels, such as coal, oil, and natural gas. (The remainder is from the burning of biofuels, waste, and wood.)[2] As we burn fossil fuels and waste, we release carbon dioxide (CO_2) into the atmosphere. This carbon dioxide acts like a blanket, trapping heat – and the trapped heat is changing our climate, causing more extreme weather, sea level rise, and more.

Increasingly, houses, businesses, and transportation can run on electricity. More and more electric utilities are sourcing electricity from wind, solar, and hydropower. But as was said in the episode, industrial processes like making steel, requires a lot of consistent and reliable heat, which can be difficult to get entirely from clean energy.

As Dr. Ikonnikova says in the podcast episode, hydrogen has the potential to be a fuel for heavy industry – but without the carbon dioxide emissions.

1 International Energy Agency https://www.iea.org/reports/key-world-energy-statistics-2020/emissions
2 International Energy Agency, Report Extract: Final Consumption 2020 https://www.iea.org/reports/key-world-energy-statistics-2020/
3 International Energy Agency, Total Energy Supply by Source, 2019 https://www.iea.org/data-and-statistics/data-browser

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How Much Energy?

How much energy (for electricity and heat) does industry use each year? How much carbon dioxide does that release into the atmosphere? You will collect data from a series of charts and use the resulting information to answer these questions.

The charts can be found at https://www.iea.org/reports/key-world-energy-statistics-2020 under **Emissions** and **Final Consumption**. Mouseover each section of the pie chart to get the total Mtoe (million tonnes oil equivalent).

- World CO_2 Emissions From Burning Fossil Fuels, 2018
- World coal final consumption by sector, 2018

  Categories: Iron & Steel, Chemical & Petrochemical, Non-metallic minerals, and Other Industry
- World oil final consumption by sector, 2018

  Category: Industry
- World natural gas final consumption by sector, 2018

  Category: Industry

Fuel	% World CO_2 Emissions	Mtoe Used by Industry	Total Mtoe	% Used by Industry
Coal				
Oil				
Natural Gas				
Total				

Discussion

- What percentage of fossil fuel energy is used by industry each year?
- Hydrogen can replace some fossil fuel use by industry. Which fuel would you focus on replacing with hydrogen to have the biggest impact on carbon dioxide emissions?
- What other questions do you have, based on the statistics you saw from the International Energy Agency?