Today I Learned About Hydrogen Energy

Description:

Hydrogen has the potential to replace fossil fuels in many sectors of the economy. Students learn about how (and where) hydrogen can be produced from renewable energy, how batteries and fuel cells work, and where hydrogen could replace fossil fuels. They are challenged to explain batteries and fuel cells to another audience.

Skills & Objectives

SWBAT

- Compare and contrast a battery and a fuel cell.
- Describe how hydrogen is generated.
- Understand how and where hydrogen might be able to replace fossil fuels.

Skills

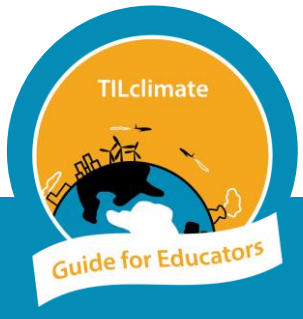
- Comparing and contrasting
- Communication
- Map-reading
- Graph reading

Students Should Already Know That

Substances such as air, methane, and water are made up of molecules that can be split to form other molecules.

Standards Alignment:
HS-ETS1-3 Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs.
HS-PS2-6 Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.
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.A Natural Resources
ESS3.D Global Climate Change
ETS1.B Developing Possible Solutions



Today I Learned About Hydrogen Energy

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

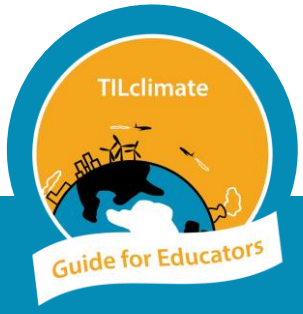
All student pages are designed to be printable in grayscale, except for the maps on pages 2-4 and the diagrams on pages 6+7. A few copies of this page could be printed color for students to share, or the image projected in the classroom.

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 Statistics

Fuel	% World CO_2 Emissions (A)	Mtoe Used by Industry (B)	Total Mtoe (C)	% Used by Industry (C/B)
Coal	44%	726.2	994	73.1%
Oil	34.1%	292	4,051	7.2%
Natural Gas	21.2%	597.9	1,611	37.1%
Total	99.3%	1,616.1	6,656	24.3%

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.



Today I Learned About Hydrogen Energy

Detailed Table of Contents

Water Electrolysis Demonstration

Complete video instructions, safety information, and materials list:
https://www.exploratorium.edu/snacks/having-gas-with-water

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Hydrogen Fuel Cells

This Educator Guide includes a map-reading exercise, a communication challenge, and data analysis. 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: How batteries and fuel cells work.
- Life/environmental science: The impacts of hydrogen vs other fuel sources.
- History/social science: History of batteries and fuel cells.
- ELA/literature: Connections to futuristic literature.
- ELA/nonfiction: Communication about a complex scientific topic.

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

  Chapter 10

- MIT Climate Portal Explainers are one-page articles describing a variety of climate topics. New Explainers are posted monthly. https://climate.mit.edu/explainers

  Hydrogen

  Energy Storage

  Renewable Energy

  Greenhouse Gases

Today I Learned About Hydrogen Energy

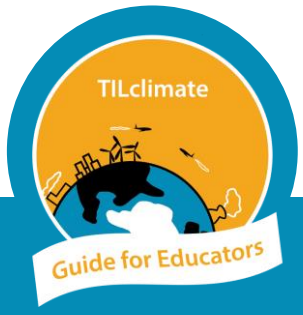
Wrap-Up Discussion Questions

- Where in the world is best suited to using solar or wind power to generate hydrogen fuel?
- How can hydrogen replace other forms of energy?
- What is the difference between a battery and a fuel cell? Where would you use one instead of the other?
- 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?

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 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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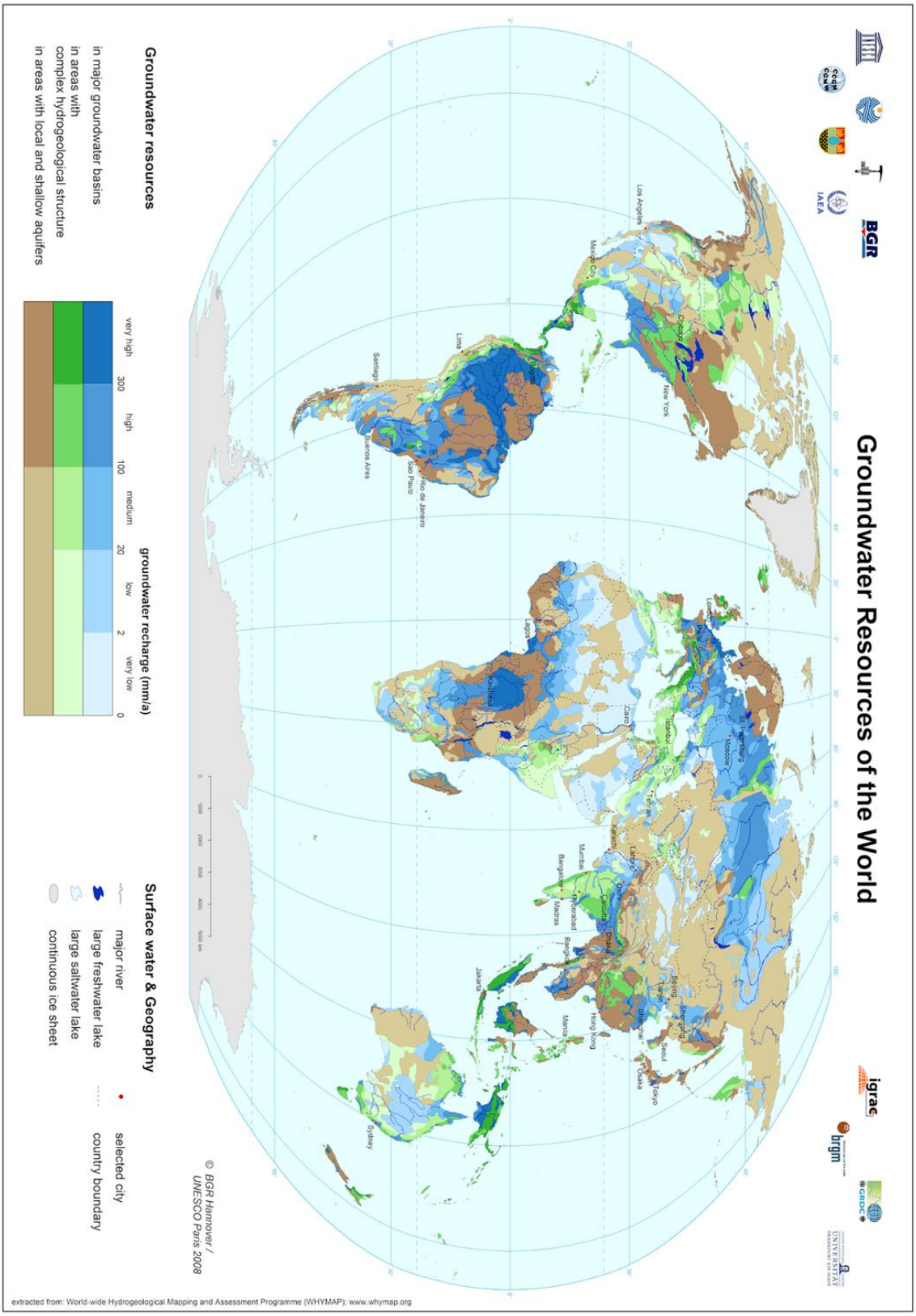

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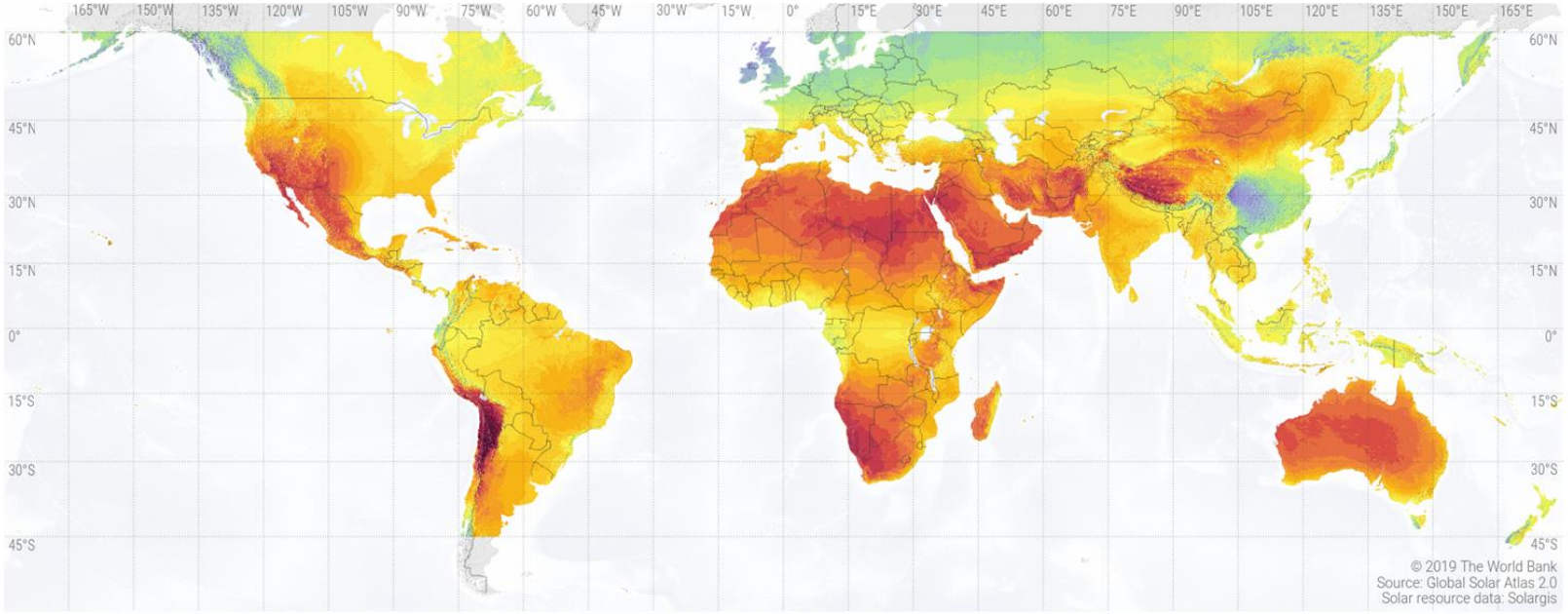
SOLAR RESOURCE MAP

PHOTOVOLTAIC POWER POTENTIAL

WORLD BANK GROUP ESMAP SOLARGIS



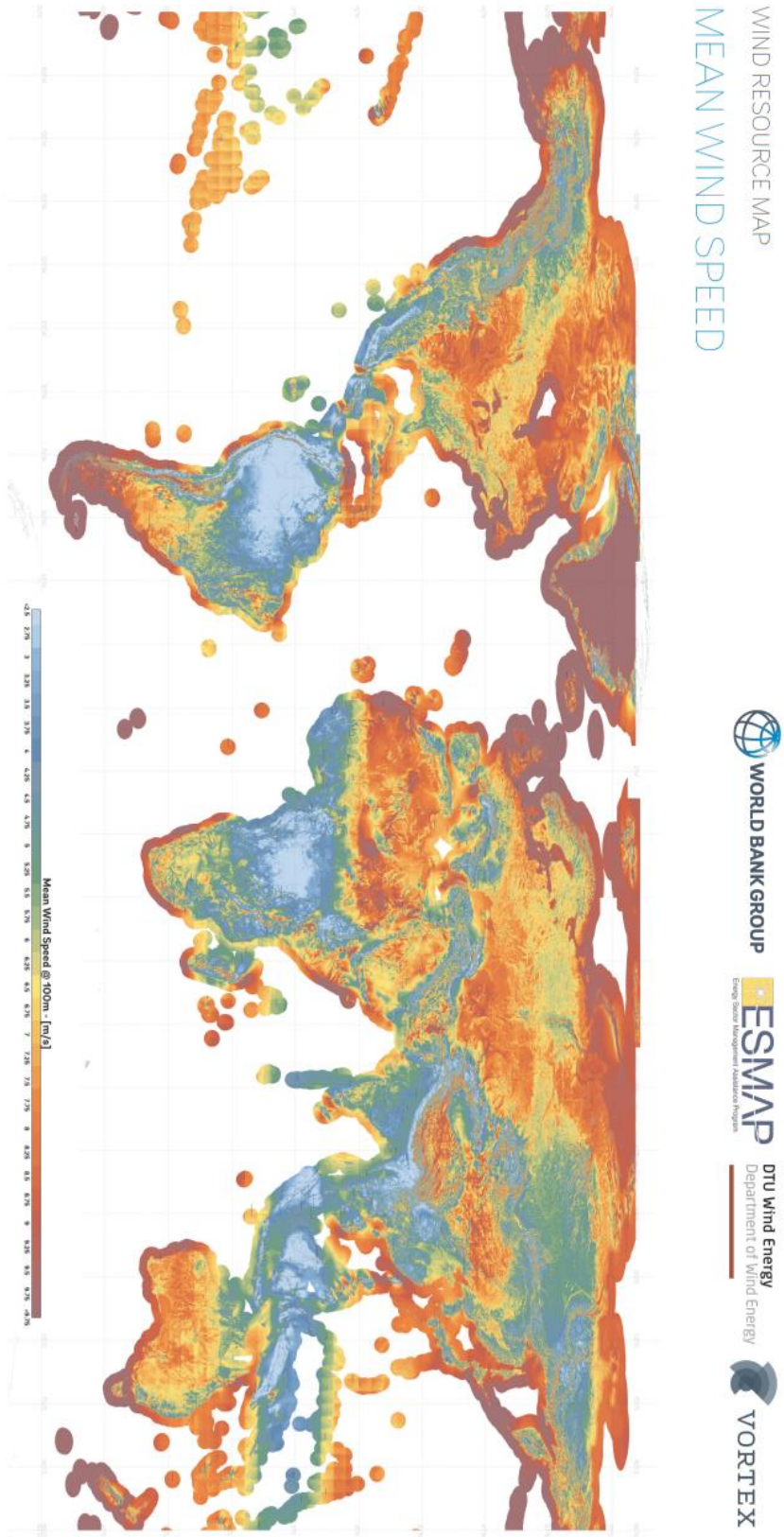
Long-term average of photovolaic power potential (PVOUT)

Daily totals:	2.0	2.4	2.8	3.2	3.6	4.0	4.4	4.8	5.2	5.6	6.0	6.4
												kWh/kWp
Yearly totals:	730	876	1022	1168	1314	1461	1607	1753	1899	2045	2191	2337

This map is published by the World Bank Group, funded by ESMAP, and prepared by Solargis. For more information and terms of use, please visit http://globalsolaratlas.info.

ENVIRONMENTAL SOLUTIONS INITIATIVE

Today I Learned About Hydrogen Energy



ENVIRONMENTAL SOLUTIONS INITIATIVE

Today I Learned About Hydrogen Energy

"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
TILclimate podcast: Today I Learned About Hydrogen Energy

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

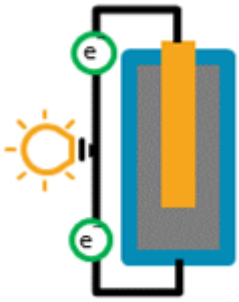
Choose one of the following topics based on the diagrams you looked at:

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.

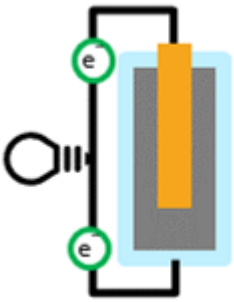
In your group, decide how you would like to explain this topic to someone else. You could use code, blocks, magnets, animation, illustration, video, interpretive dance… the possibilities are endless. Your goal is to help the audience of your choice understand the topic and how it relates to their life.

Today I Learned About Hydrogen Energy

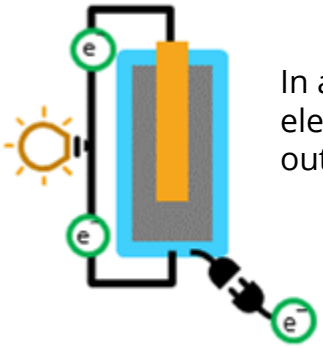
Batteries



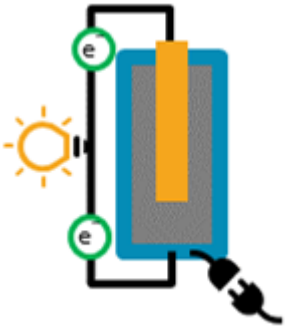
In most batteries, a metal (blue) *oxidizes*, which sends electrons (green circles) along a wire (black), generating an electrical current and lighting the lightbulb. Another metal (yellow) *reduces*, taking in the electrons. An *electrolyte* (gray) allows the electrical charge to pass between the two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



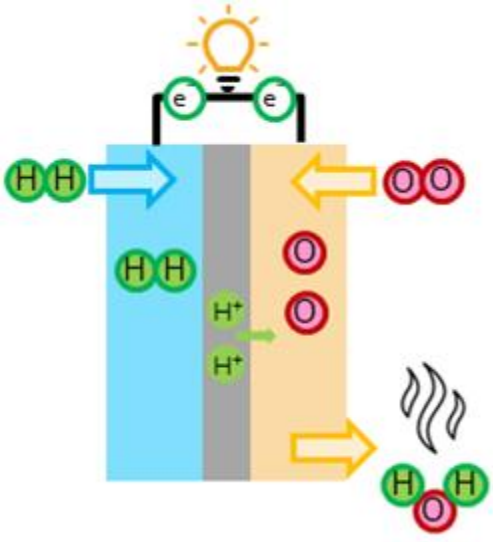
Each time the battery is used and recharged, the *oxidizing* metal can only recharge partway, and the battery loses charge more quickly.

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

Today I Learned About Hydrogen Energy

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.

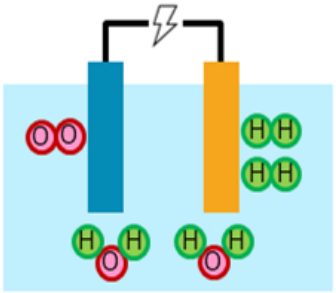
The *protons*, *electrons,* and oxygen atoms combine to form water vapor (H_2O) and heat.

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).

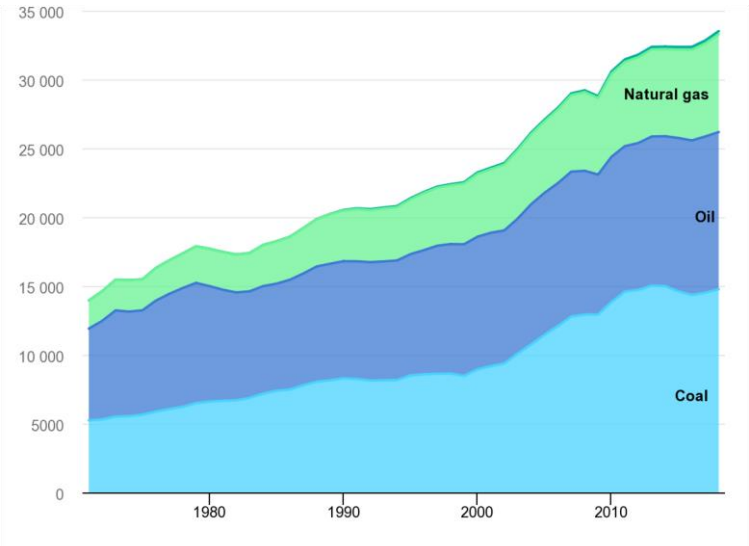
An electrical current passes between two poles, which are both partially submerged in water. This splits the water molecule (H_2O) and the atoms reform into hydrogen gas (H_2) and oxygen gas (O_2), which bubble out.

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

Today I Learned About Hydrogen Energy

"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
TILclimate podcast: Today I Learned About Hydrogen Energy



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

Today I Learned About Hydrogen Energy

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?