Today I Learned About Wind and Solar Power

"Instead of burning a fuel that contains carbon, renewable technologies convert either the kinetic energy in air or in water (in the case of wind and hydro) into electricity, or they convert light into electricity (that would be photovoltaics)."

Magdalena Klemun, Institute for Data Systems and Society, MIT

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Where Does Energy Come From?

Most of the energy used in the US (for heat, light, transportation, and everything else) comes from fossil fuels such as oil, coal, and natural gas. Burning these fuels releases carbon dioxide (CO_2) into the atmosphere. While a regular amount of CO_2 is needed to support life on Earth, the rampant addition from burning fossil fuels is changing our climate. In the atmosphere, CO_2 acts like a blanket, trapping heat. This extra heat is warming our Earth, ocean, and air – changing climate and weather patterns like storms, droughts, and heat waves.

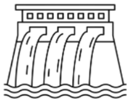
Generating Electricity

Most power plants generate electricity by turning a turbine. A turbine is basically a large wheel with magnets on it. Moving a magnet inside a coil of wire makes an electric current flow through the wire. This electric current can be used directly or stored, such as in a battery. Below are a list of energy sources that use a turbine, plus one that doesn't.

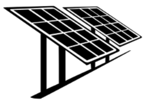
In coal- or natural-gas-powered plants, the fuel is burned to boil water and create steam. This steam spins the turbine.

Nuclear power plants use the heat of radioactivity to boil water for a steam-powered turbine.

Wind turbine blades turn when the wind blows, which spins a turbine.



Hydropower uses the push of water from a dam to turn a turbine.



Solar photovoltaics do not involve a turbine. Sunlight is absorbed by the solar panel, which causes a process that dislodges electrons and creates electricity.

Images from The Noun Project by Leonardo Schneider, Panyawut Norrasing, Lucas Helle, Vectors Point, Tom Fricker, and Adam Terpening

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"Wind and solar electricity are available when the wind blows and when the sun shines. But that's sometimes, but not always when consumers demand energy."
Magdalena Klemun, Institute for Data Systems and Society, MIT
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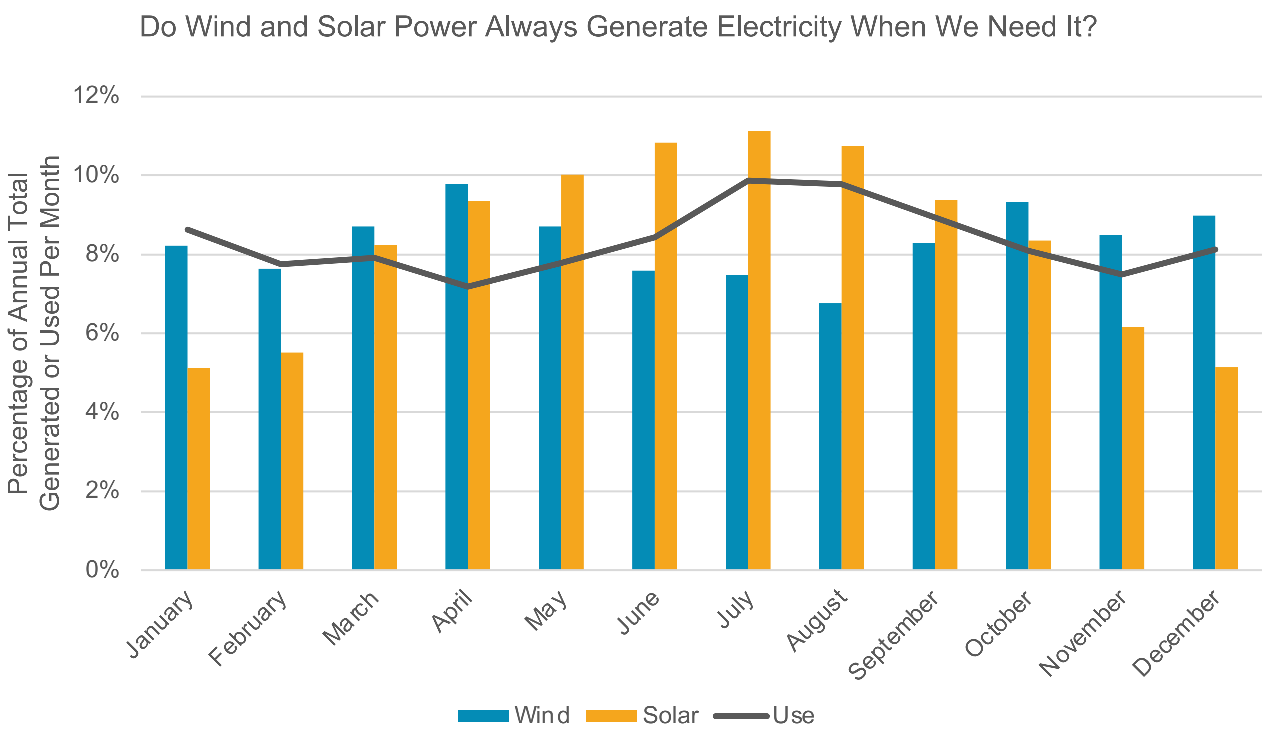
When the Wind Blows and the Sun Shines

Every part of the world has sun and wind. However, those resources are naturally variable over time and location. Do we have enough solar and wind energy in the US to generate all our electricity?

Wind and solar energy vary by month, but so does electricity use in the U.S. In the graph below, the percent of total electricity generated by wind turbines and solar panels in the United States each month are shown in bars. The percent of total electricity used each month is shown as a line.

Since solar and wind are currently a small share of total energy generated and used in the US, all data are shown as a percentage of total instead of their absolute value. (Data are from 2019)



Data from the Energy Information Administration, https://www.eia.gov/electricity/annual/html/epa_03_01_b.html
https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_5_01

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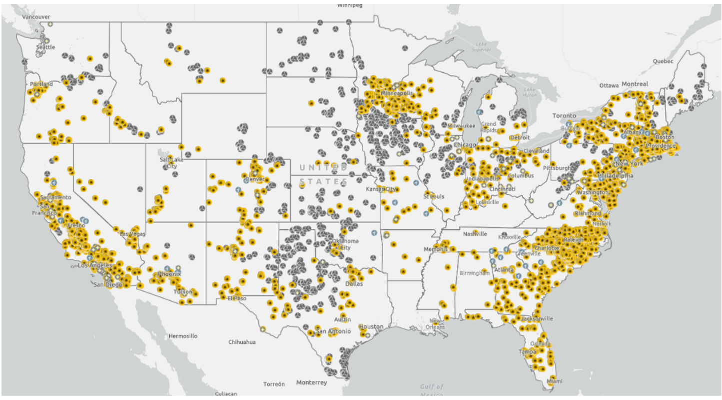
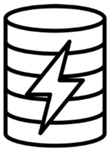


Utility-scale solar plants, wind farms, battery storage, and pumped storage locations in the US.

Solutions

Wind and solar are variable, but what if we could store extra energy for when we needed it? Energy storage has many forms, but the most common in use today are batteries and pumped energy.



Large-scale batteries can be charged when power is abundant and used when there is less electricity being produced.

Pumped storage facilities pump water into a reservoir when there is excess electricity, and then generate electricity with a hydroelectric turbine when needed.

Questions

1. Which months have the highest electricity demand? Why do you think this is?
2. Which months produce the highest amount of wind and solar electricity? Why do you think this is?
3. Do the two patterns align? Are the most productive months for solar and wind the same as the months when the US uses the most electricity?
4. How could changes in storage and transmission technology help?
5. What other questions do you have? How could you investigate these questions?

Data from the Energy Information Administration, https://atlas.eia.gov/apps/all-energy-infrastructure-and-resources/explore
Images from The Noun Project by Abdul Latif and Sahua D

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"The economics are different across locations, but also every single country on this planet has direct access to solar and wind energy. And so that's pretty unique for an energy source. If you consider, for example, that 70% of global resources of natural gas are concentrated in five countries."

Magdalena Klemun, Institute for Data Systems and Society, MIT

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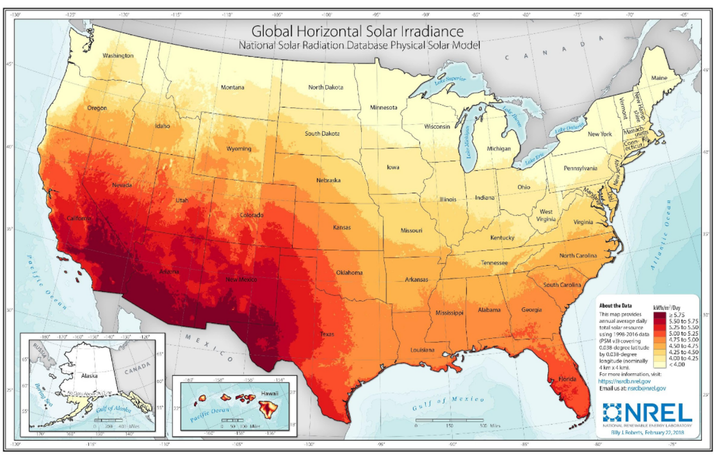
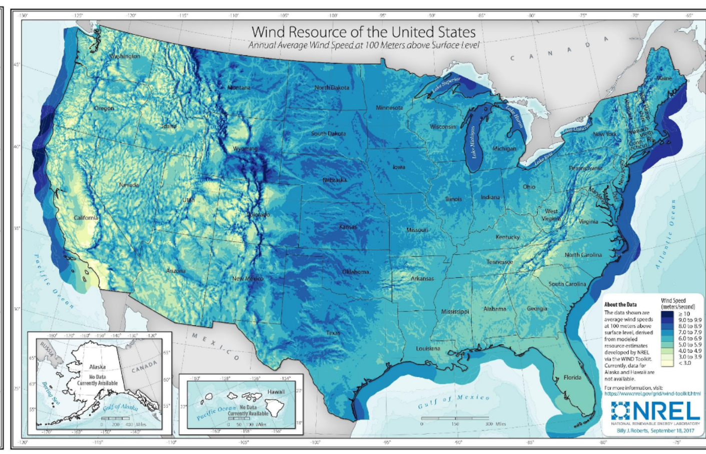
Where the Wind Blows and the Sun Shines

Even within the US, solar and wind resources are not distributed evenly. Parts of the country are famous for being sunny year-round, while others are famous for being gray and rainy. Wind varies by location and by height above the ground.



Annual average daily solar resources. Lightest colors <4 kWh/m^2/day, darkest colors >5.75 kWh/m^2/day



Annual average daily wind resources at 100 meters above the surface. Lightest colors <3 m/sec, darkest colors >10 m/sec

Questions

1. What patterns do you notice in wind and solar resources? Why do you think this is?
2. Where would you build large-scale solar or wind farms?
3. In areas with low wind and solar resources, what factors would help decide whether a solar or wind farm was worth building? (Consider local electricity needs.)
4. Where do you think the majority of utility-scale solar power plants are? Wind power plants? Make a prediction.

Maps from the National Renewable Energy Laboratory
https://www.nrel.gov/gis/assets/images/solar-annual-ghi-2018-usa-scale-01.jpg https://windexchange.energy.gov/maps-data/324

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"Renewable energy technologies have proven easy to scale. So all we need to do to build a megawatt scale solar photovoltaic plant instead of a small rooftop system is to put more solar panels in a row and more rows next to each other."
Magdalena Klemun, Institute for Data Systems and Society, MIT
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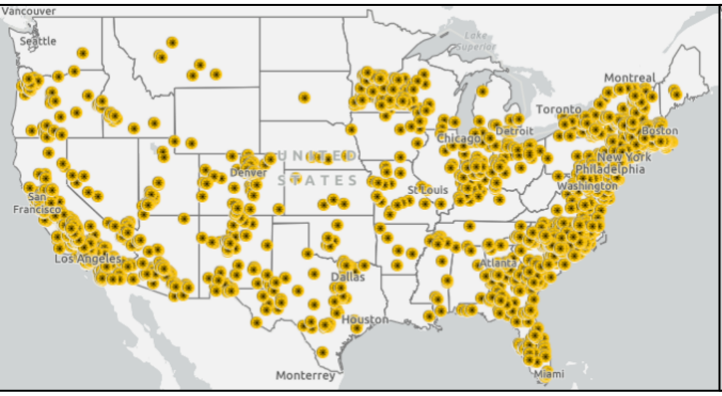
Where are the Wind and the Sun are Harnessed

Utility-scale solar and wind power plants are not evenly distributed around the US. Power plants are considered 'utility-scale' when they produce energy for multiple homes and businesses (as opposed to rooftop solar or a small turbine for a single business.) Project placement and growth are impacted by resources, economics, politics, geology, population density, and other factors.



Utility-scale solar plants

Utility-scale wind plants

Questions

1. What patterns do you notice in the locations of wind and solar plants? Why do you think this is?
2. Were you correct in your predictions about where they would be? Why or why not?
3. What factors do you think influence where these plants are built?
4. How would you investigate these influences?
5. Would you support a large-scale wind plant in your community? Why or why not?
6. Would you support a large-scale solar plant in your community? Why or why not?
7. What other questions do you have about wind and solar? How could you investigate these questions?

All maps from https://atlas.eia.gov/apps/all-energy-infrastructure-and-resources/explore. Energy Information Administration, October 2020

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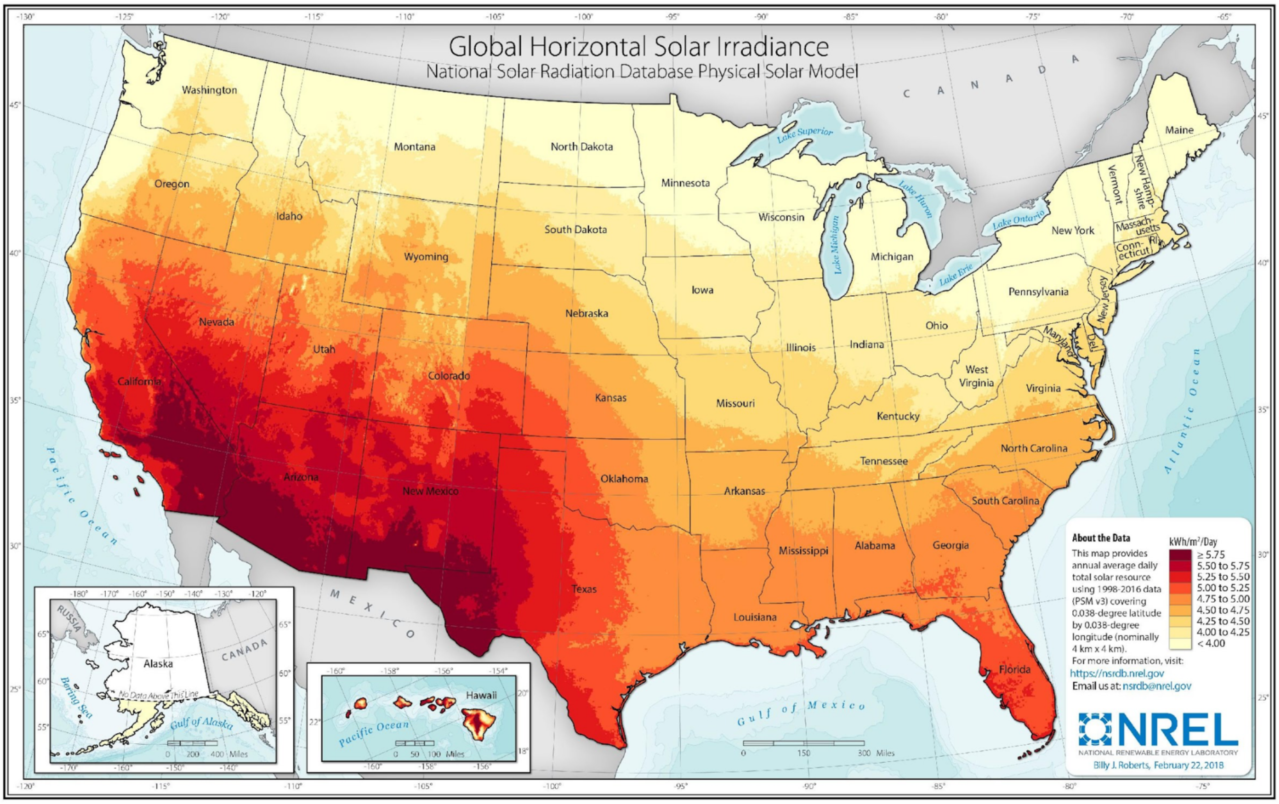

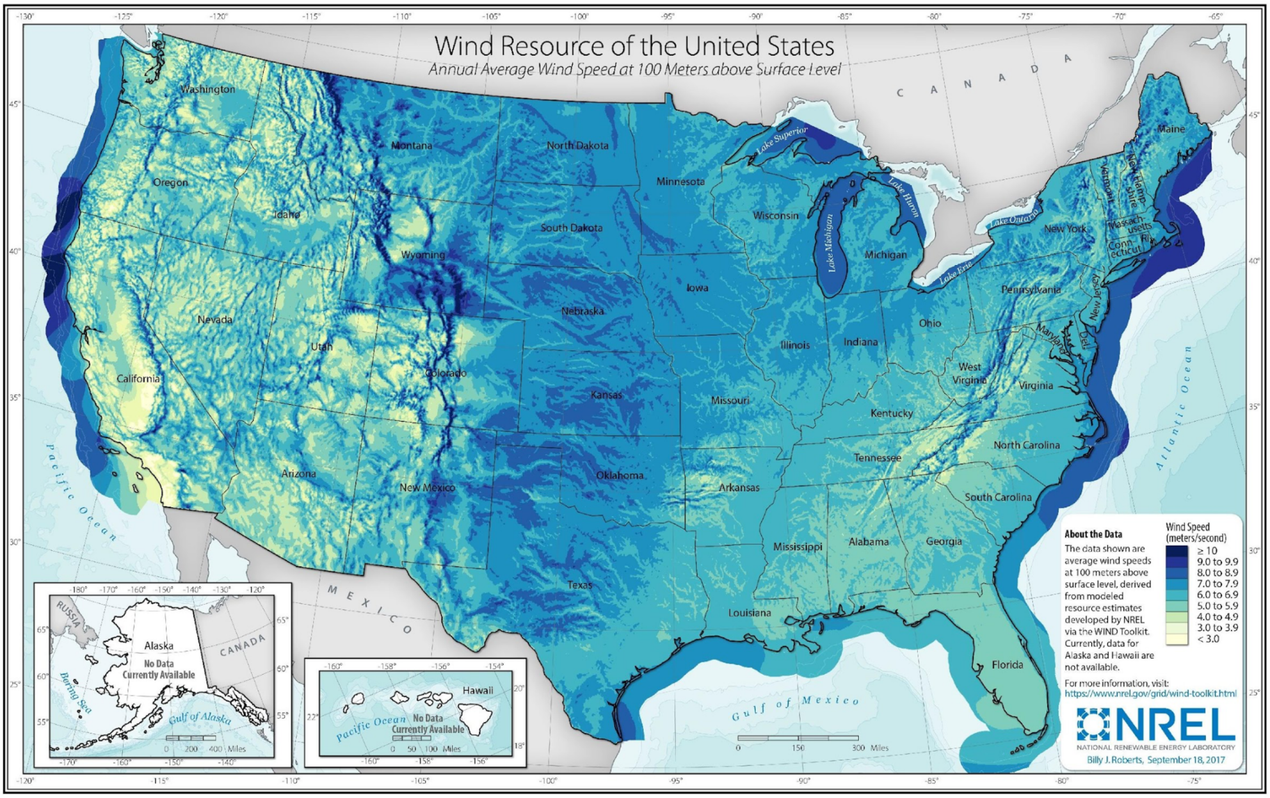

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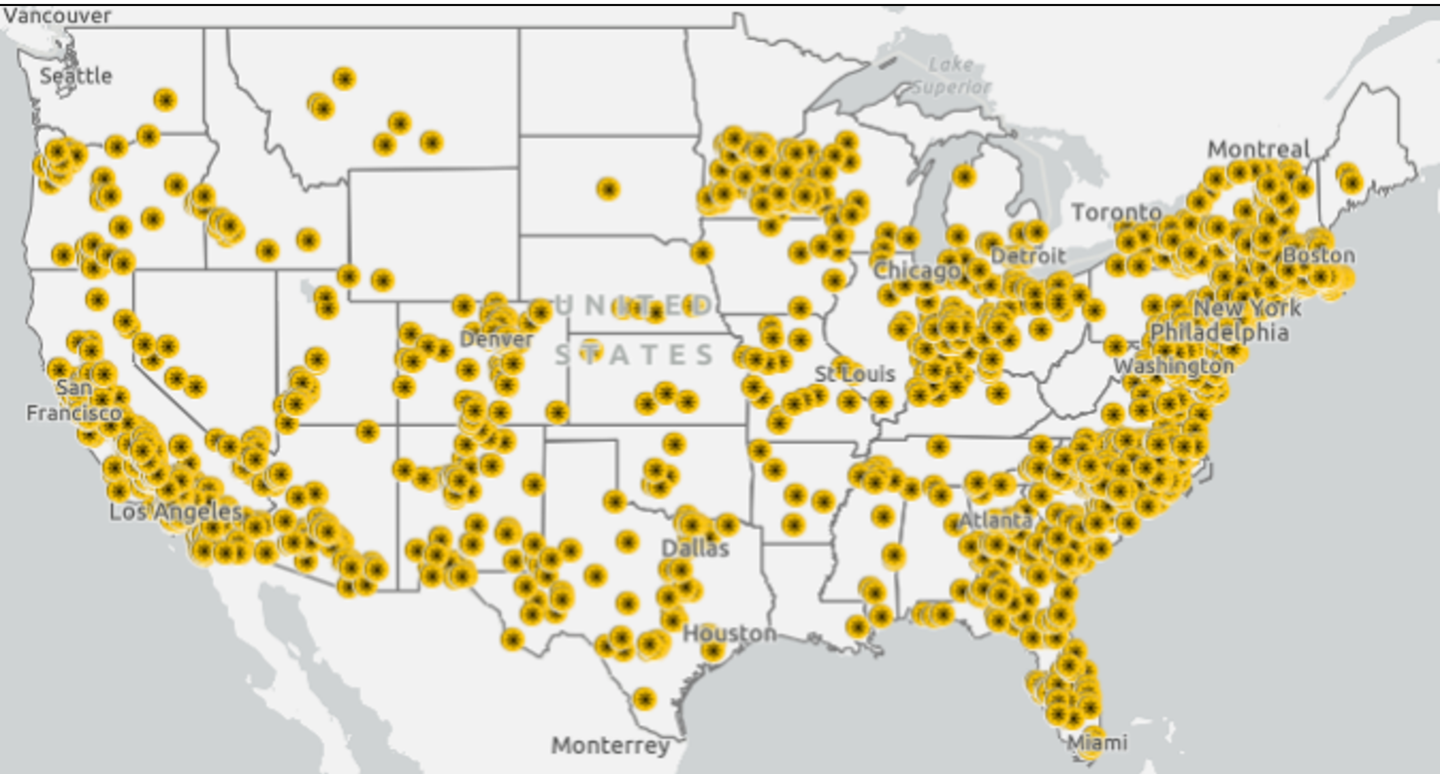

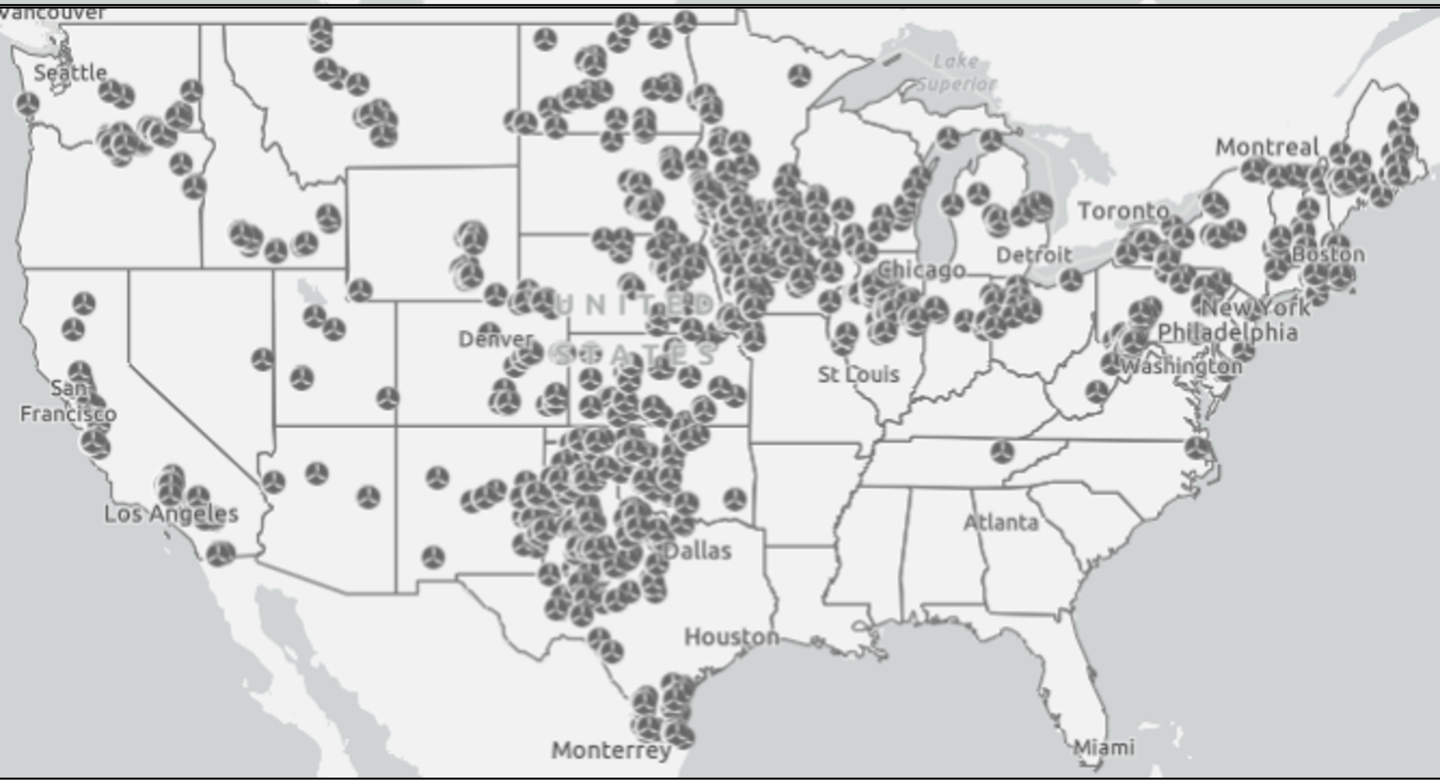

All maps from https://atlas.eia.gov/apps/all-energy-infrastructure-and-resources/explore. Energy Information Administration, October 2020

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"The term energy storage refers to a class of technologies that capture energy available at one point in time to make it available at another point in time."

Magdalena Klemun, Institute for Data Systems and Society, MIT

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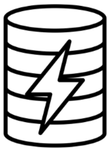
More Research Needed

Carbon dioxide (CO_2) in the atmosphere acts like a blanket around Earth, trapping heat. A regular amount of CO_2 is needed in our atmosphere to support life on Earth, but rampant extra CO_2 is warming the Earth too quickly. This extra warming leads to dramatic changes in weather and climate patterns, including storms, drought, and heat waves. About one quarter of all US carbon emissions come from burning fossil fuels like coal, oil, and natural gas for electricity[1].

Wind and solar energy release some CO_2 during construction, but little to none during operation. In order to slow climate change, we need to replace high-carbon energy sources with low-carbon ones. Wind and solar are two tools in our toolbox, but like all tools they have their strengths and drawbacks.

The sun shines during the day, but we want lights at night. It is less windy in the summer, when there is more need for air conditioning. Wind and solar are considered "intermittent" energy sources, and they are not equally distributed. To even out the distribution and availability of this energy, we need energy storage. Extra electricity generated on sunny and windy days can be stored to use at night or on calm days.



Energy storage is a growing field with many possibilities, but no single technology yet exists that can store all the energy we will need. Research is needed and ongoing to develop energy storage that is efficient, inexpensive, and can be widely available.

Background Reading

Before you begin your research, read the following short articles.

- MIT Explainer: Energy Storage https://climate.mit.edu/explainers/energy-storage
- Solar-Plus-Storage 101 https://www.energy.gov/eere/solar/articles/solar-plus-storage-101
- An introduction to the state of energy storage in the U.S. https://yaleclimateconnections.org/2019/12/an-introduction-to-the-state-of-energy-storage-in-the-u-s/
- EPA: Electricity Storage https://www.epa.gov/energy/electricity-storage

1 https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions

Images from The Noun Project by Laymik and Abdul Latif

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Energy Storage Research

1. As a group, make a list of the major types of energy storage.
2. From what you have read or what you know previously, note a few strengths and weaknesses for each type of storage technology.
3. Individuals or pairs in your group each choose one type of energy storage to research.
4. As a group, create questions that you want to answer about energy storage. Consider factors like efficiency, environmental impact, cost, and the lifetime of the product.
5. As a group, consider which kinds of resources will help you in your research. Internet searches will most likely give you the most up-to-date information, but keep in mind the sources you are looking at. (Who is more likely to give you good information: a scientific or government research site, or a company trying to sell storage technology?)
6. As a group, determine how you will share your learning with each other. Will you formally present to one another, share notes in a digital document, or something else?
7. Begin your research. Each member or pair in your group will investigate one form of energy storage, but everyone will answer the same questions you generated.

Share Out

8. Once you have completed your research, teach the other members of your group what you have learned. Depending on the length of your project and what your group determined in step 6, this may take various forms.
9. After each member of your group has had a chance to teach the others what they learned, discuss:
   - Which energy storage technologies do you find the most promising? Why?
   - What do you still wonder about energy storage? How could you find the answers to these questions, or do the answers exist?
10. Choose an audience that needs to know about energy storage. Design something that introduces this audience to the subject, explains why it is important to them, and directs them towards resources.

Citation