Today I Learned About Wind and Solar Power

Description:

Wind and solar power are key tools in the climate change toolkit – but what are their strengths and weaknesses? Can they provide us with all the clean electricity we need? Students investigate wind and solar resources and electricity needs. Then, they research the growing field of energy storage and share their results with a key audience.

Skills & Objectives

SWBAT

- Explain why wind and solar power are important parts of a low-carbon future.
- Explain why energy storage is needed to harness the potential of wind and solar.

Skills

- Map reading and spatial analysis
- Research methods

Students Should Already Know That

- Electricity is produced through a variety of methods, including fossil fuel burning, wind, solar, hydroelectricity, and others.

Standards Alignment:
HS-ESS3-1 The availability of natural resources have influenced human activity.
HS-ESS3-2 Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources
HS-ESS3-4 Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.
HS-ETS1-3 Evaluate a solution to a complex real-world problem based on prioritized criteria.
RST.11-12.2 Determine the central ideas or conclusions of a text.
RST.11-12.9 Synthesize information from a range of sources into a coherent understanding of a process, phenomenon, or concept.
Disciplinary Core Ideas:
ESS2.A Earth Materials and Systems
ESS3.C Human Impacts on Earth Systems
ETS1.B Developing Possible Solutions

Today I Learned About Wind and Solar Power

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, including the maps on pages 3 and 4. Larger versions of these maps are included. A few copies of these pages 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.

On page 5, students are assigned four articles. Depending on time and your goals, students may read all four articles or individual students may each read one article and teach the other members of their group what they learned.

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 Wind and Solar Power

Detailed Table of Contents

Today I Learned About Wind and Solar 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.

Wind, Solar, and Energy Storage

This Educator Guide includes a map investigation and a research project. 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: Solar, wind, and energy storage technology.
- Life/environmental science: Impacts of fossil fuel use on climate change. Impacts of solar and wind technology on the environment.
- History/social science: Research methods.
- ELA/nonfiction: Research methods.

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 10 What can we do?
- MIT Climate Portal Explainers are one-page articles describing a variety of climate topics. https://climate.mit.edu/explainers
    - Renewable Energy
    - Energy Storage

Today I Learned About Wind and Solar Power

Wrap-Up Discussion Questions

- 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.)
- What factors do you think influence where these wind and solar plants are built?
- Which energy storage technologies do you find the most promising? Why?
- What other forms of low-carbon electricity are part of the energy toolkit?
- What other questions do you have about wind, solar, and energy storage? How could 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?

TILclimate
Guide for Educators

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 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
TILclimate podcast: Today I Learned About Wind and Solar Power

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.

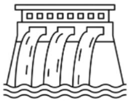
Generating Electricity

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.

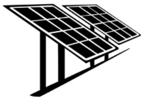
In coal- or natural-gas-powered plants, the fuel is burned to boil water and create steam. This steam spins the turbine.

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

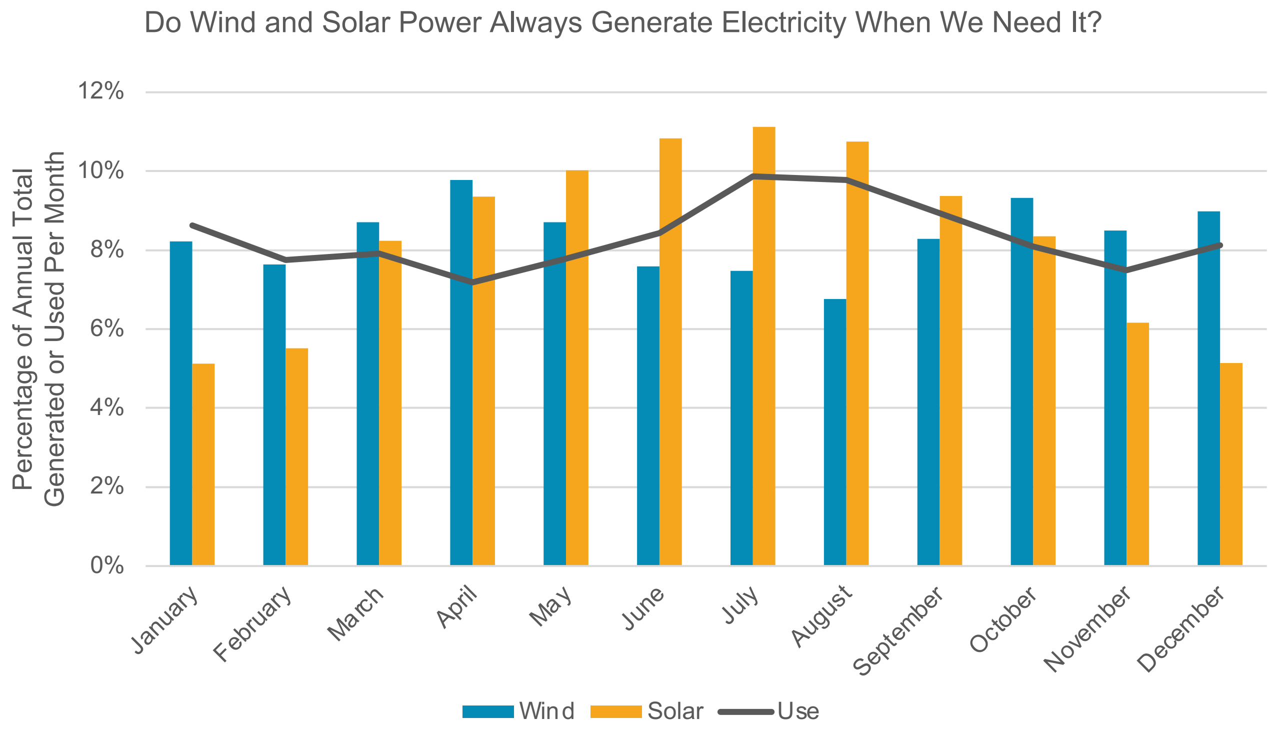
TILclimate podcast: Today I Learned About Wind and Solar Power

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?

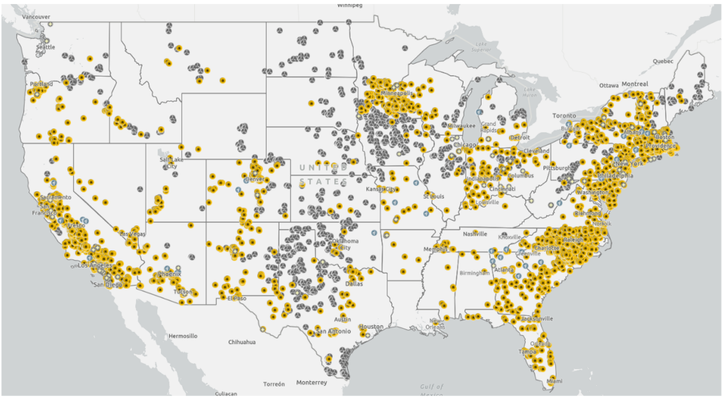
Wind and solar energy vary by month, but so does electricity use in the U.S. In the graph below, the percent of total electricity generated by wind turbines and solar panels in the United States each month are shown in bars. The percent of total electricity used each month is shown as a line.

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

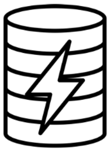
Today I Learned About Wind and Solar Power



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

Today I Learned About Wind and Solar Power

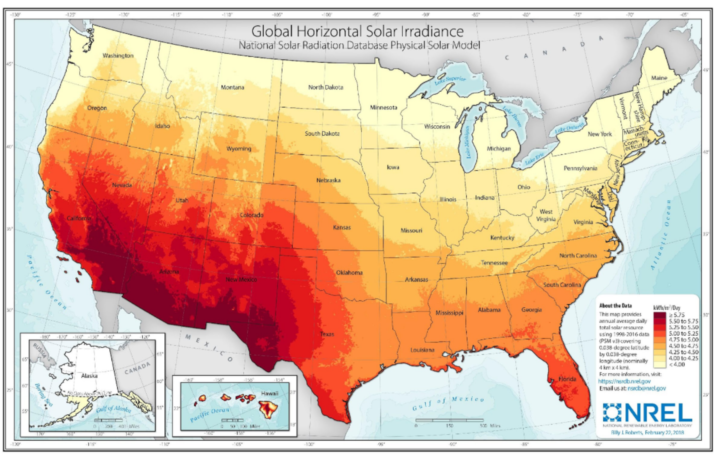
"The economics are different across locations, but also every single country on this planet has direct access to solar and wind energy. And so that's pretty unique for an energy source. If you consider, for example, that 70% of global resources of natural gas are concentrated in five countries."

Magdalena Klemun, Institute for Data Systems and Society, MIT

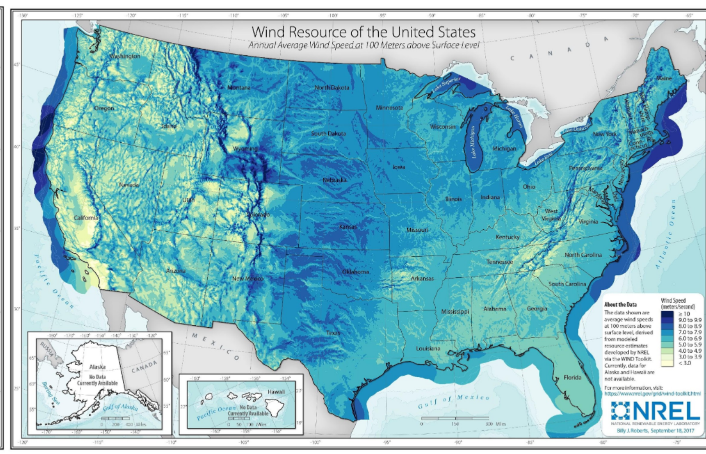
TILclimate podcast: Today I Learned About Wind and Solar Power

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/m²/day,
darkest colors >5.75 kWh/m²/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.

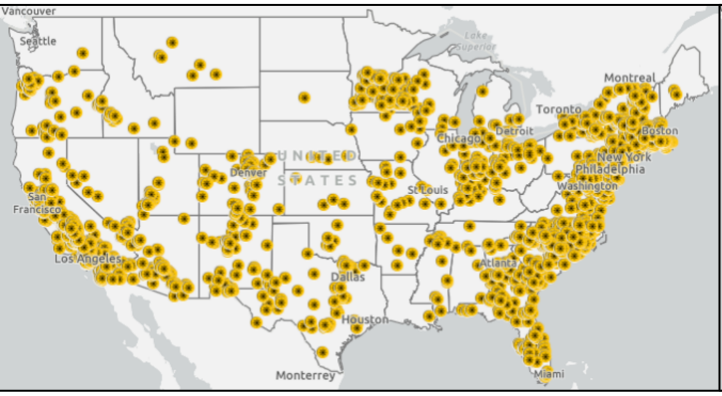
Maps from the National Renewable Energy Laboratory
https://www.nrel.gov/gis/assets/images/solar-annual-ghi-2018-usa-scale-01.jpg https://windexchange.energy.gov/maps-data/324

Today I Learned About Wind and Solar Power

“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
TILclimate podcast: Today I Learned About Wind and Solar Power

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

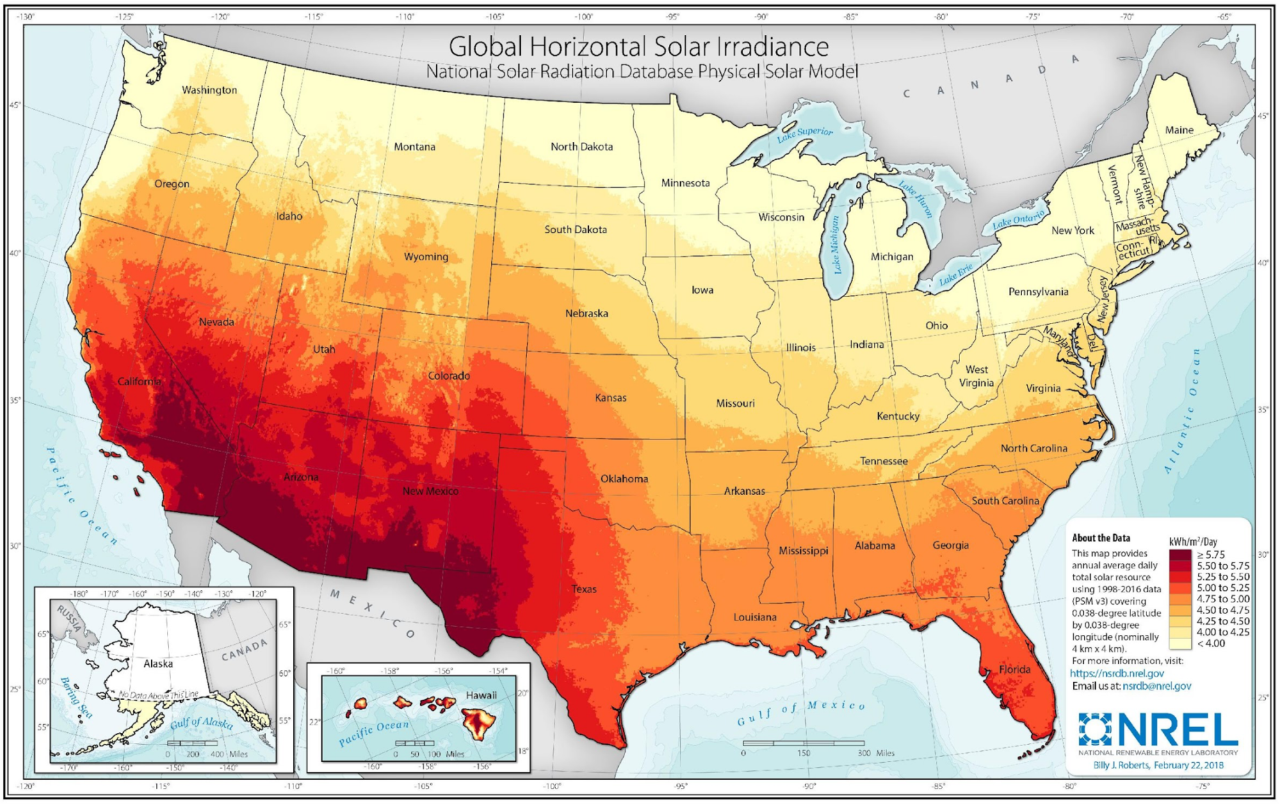
Utility-scale wind plants

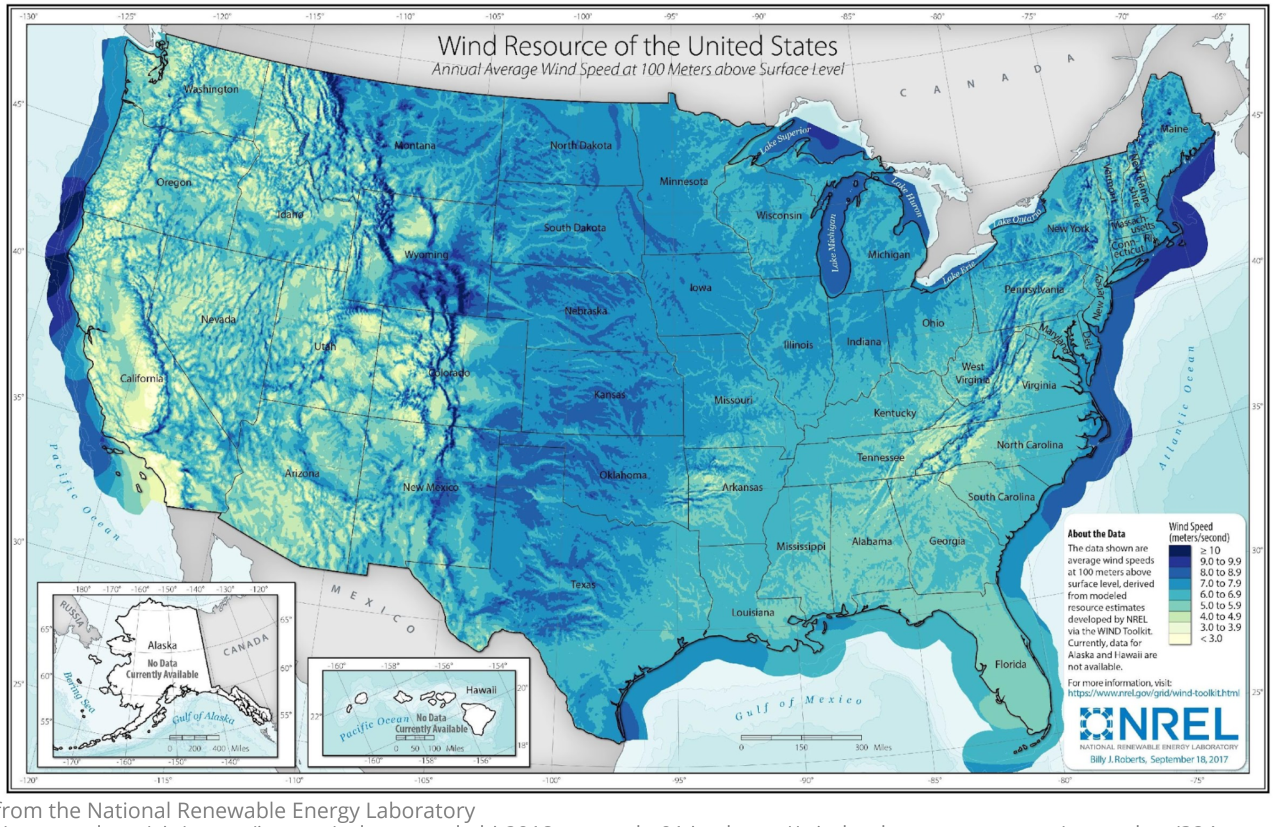
Questions

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

Today I Learned About Wind and Solar Power





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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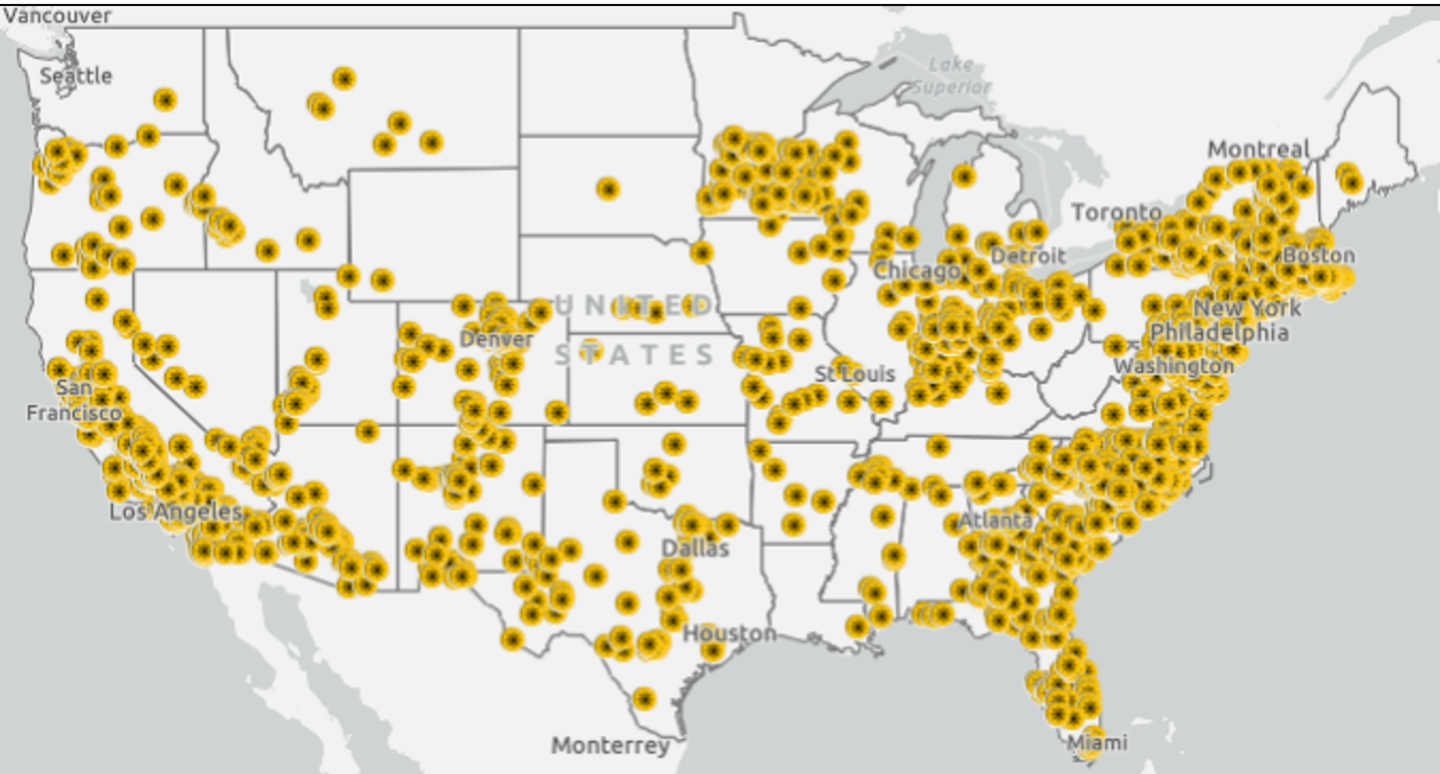
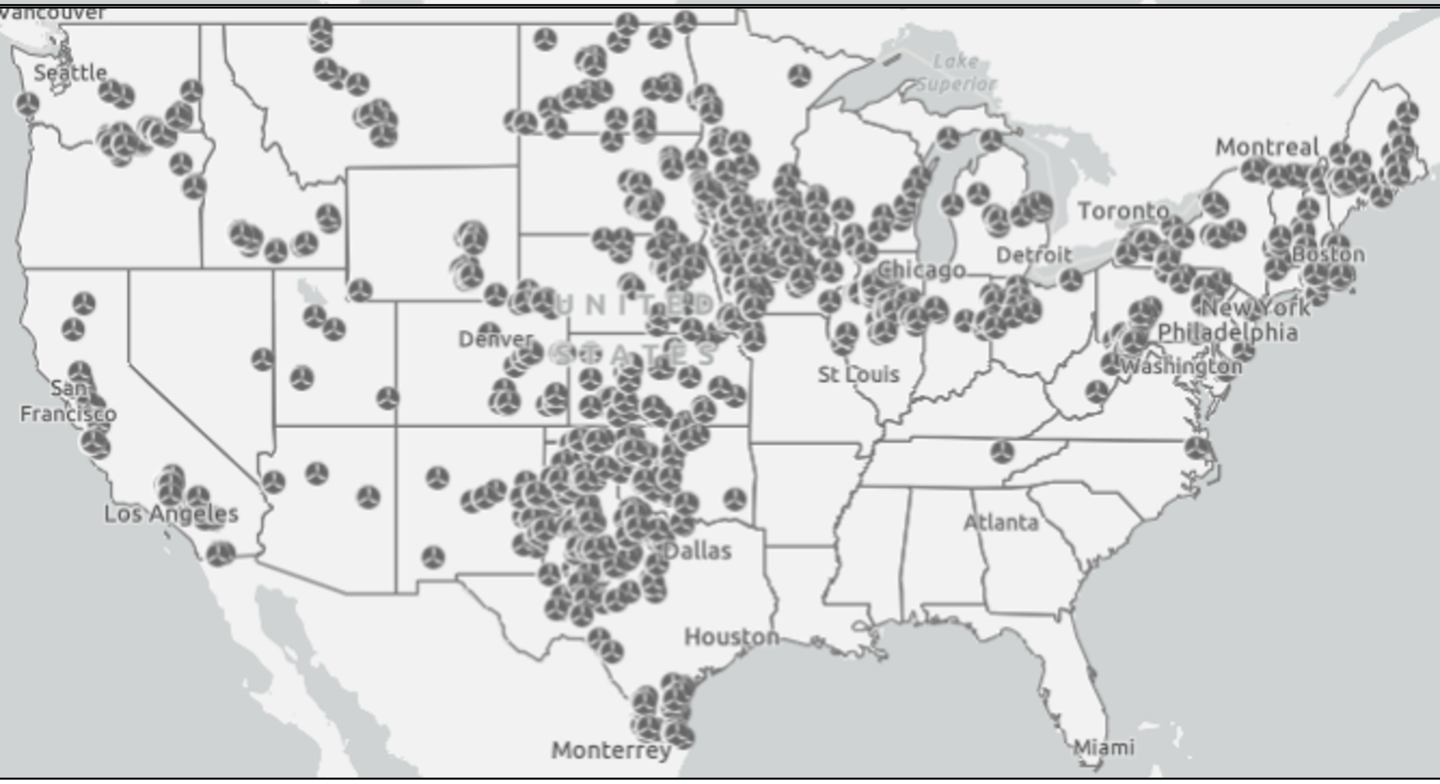




All maps from https://atlas.eia.gov/apps/all-energy-infrastructure-and-resources/explore. Energy Information Administration, October 2020

Today I Learned About Wind and Solar Power

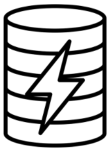
"The term energy storage refers to a class of technologies that capture energy available at one point in time to make it available at another point in time."
Magdalena Klemun, Institute for Data Systems and Society, MIT
TILclimate podcast: Today I Learned About Wind and Solar Power

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

Today I Learned About Wind and Solar Power

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