Today I Learned About The Electric Grid

Description:

The electric grid is an invisible and yet deeply necessary part of modern life. Through a game, students understand the challenges of keeping the grid balanced. Students explore two map-based datasets to explain why and how the grid stays balanced. A deeper dive into their own local electric grid makes the learning relevant.

Skills & Objectives

SWBAT

- Explain why the electric grid needs to be balanced over space and time.
- Evaluate choices made in a region in terms of how electricity is generated and transmitted.

Skills

- Map reading
- Data interpretation
- Communication

Students Should Already Know That

- Electricity flows through wires in a grid across the US.
- Many different power sources are used to create electricity.
- The US is divided into Time Zones.

Standards Alignment:

HS-PS2-6 Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.

HS-ESS3-4 Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.

CCSS.ELA-LITERACY Informational Texts, Science and Technical Subjects

- Connect investigation of the local electric grid to news articles about changes to the local electric makeup.

CCSS.ELA-LITERACY.RH History/Social Studies

- The growth of the electric grid is a driving force for 20th century societal, technological, and demographic change.

Disciplinary Core Ideas:

PS3.B: Conservation of Energy and Energy Transfer

ETS1.A: Defining and Delimiting Engineering Problems

TILclimate

Guide for Educators

Today I Learned About The Electric Grid

How To Use These Activities:

Pages with the circular "TILclimate Guide for Educators" logo 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.

The game, History of Electric Grid reading, Time Zones worksheet, and Version B of the Data Exploration worksheet each take about the same amount of time. These four activities could be done as stations or a jigsaw.

Version A of the Data Exploration and both parts of the Dive Deeper activity require internet use and could be done as homework or asynchronous remote work.

A Note About Printing

Most of these pages can be printed in grayscale for student use, including the graph on page 5. However, the maps on pages 9 and 10 are in full color. In order to save on color printing, larger versions of these images have been included, which could be printed as a shared resource (1 copy for 4-5 students) or projected in the classroom.

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. Student-created podcasts are 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.

TILclimate Guide for Educators

Today I Learned About The Electric Grid

Detailed Table of Contents

Today I Learned About The Electric Grid

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.

The Electric Grid

This Educator Guide includes a game, short reading, introductory worksheets, and a deeper dive into two data-visualization websites. 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: electricity, electron movement, load-balancing, engineering
- Life/environmental science: impacts of energy use on natural systems, climate change
- History/social science: impacts of the growth of electric grids through the early 1900s, impacts of energy use and climate change on human systems
- ELA/literature: connections to 1920s and 1930s literature, rural communities, damming rivers for hydroelectricity
- ELA/nonfiction: news articles about changes to the local electric grid to include more renewable resources

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/
  - 05: How much of the CO_2 increase is natural?
  - 10: What can we do?
- MIT Climate Portal Explainers are one-page articles describing a variety of climate topics. https://climate.mit.edu/explainers
  - Cities and Climate Change
  - Energy Storage
  - Renewable Energy

Today I Learned About The Electric Grid

Wrap-Up Discussion Questions

- Electric grids can be both resilient and fragile. What contributes to the resilience and fragility of an electric grid?
- As you learned about our own local electric grid, what surprised you?
- If you were going to design the electric grid from scratch, what would you do differently?
- As we shift from fossil fuel energy that is adding to the heat-trapping blanket to renewable electricity sources like solar and wind, our electric grid needs to adapt to a changing balancing act. What are some ways that we can change the way we produce and use electricity?
- Professor Michaels talks about the combination of steps that can get us to a “climate solution”: making the electric grid mostly carbon-free, making buildings more energy-efficient, and electrifying buildings and transportation. Why is it so important to also increase the energy efficiency of buildings, rather than only electrifying them?

Climate Solutions

Climate solutions can be thought of as falling into four co-equal categories. Across all categories, a focus on community-level solutions leads to more effective action. Community-level solutions change decision-making so that the default option for individuals is the one that has the best result for the climate. For example, policies that increase the solar and wind mix in the electric grid, instead of 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 we adapt buildings to keep people safe from heat and cold?

•**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 The Electric Grid

Load-Balancing Game

Materials
- Small objects that can be passed easily from hand-to-hand. Ping-pong balls, poker chips, etc. Two per participant.

Setup
- Participants stand in a rough circle with some space between them. If a circle is not possible, make sure there is a clear order in which people are standing.
- The Electric Utility has a bucket with all the objects, plus two cups with a few extras.

Roles
- Narrator: Reads the script and directs the Electric Utility in passing out electricity.
- Electric Utility: Has the bucket of objects and passes them out as instructed.
- Buildings: Everyone else.

Playing the Game
- For each Phase, the Narrator reads the script, the Electric Utility follows the Narrator's directions, and the Buildings take the amount of electricity indicated.

Game Script & Instructions

Phase 1

Narrator Script	Electric Utility Action
You each represent a building. Take 15 seconds to decide what kind of building you are.	
This represents electricity. Take 15 seconds to think about how your building would use electricity.	Narrator holds up bucket of objects.
{Name} is the electric power plant, or electric utility. They generate electricity and send it through the wires to your buildings.	Narrator hands bucket of objects to Electric Utility.
Today is a nice, temperate day. Not too hot, not too cold. You don't need the air conditioning on, and you probably don't need the heat either. As we pass electricity around the circle, take one piece. If you have a piece, pass on to the next person. You do not need more than one, and you do not have batteries to store extra electricity.	Pass objects at a steady pace, such that everyone gets an item, and no one has to wait too long.
Our electric grid is balanced today. Our utility is producing enough electricity that you all get what you need and there isn't any extra.	Gather all objects back.

Today I Learned About The Electric Grid

Load-Balancing Game, cont'd

Phase 2

Narrator Script	Electric Utility Action
Today it is very hot. You need two times the electricity because you are running the air conditioner.	Pass objects at a faster pace, such that everyone gets two items, and no one has to wait too long.
Our electric grid has to work a lot harder to stay balanced today. It is managing to produce enough electricity.	Gather all objects back.
So far, we've been using an on-demand energy source like natural gas to power our electric grid. But, when we burn natural gas or coal for electricity, we release carbon dioxide into the atmosphere. Carbon dioxide acts like a blanket, trapping heat. The trapped heat is changing our climate. To release less carbon dioxide, this power plant is shifting over to a combination of wind and solar electricity.	

Phase 3

Narrator Script	Electric Utility Action
When we first started using wind and solar, though, we ran into a problem. Let's say it's a warm cloudy day, so some people are running their air conditioners. The wind comes and goes over the course of the day, and the clouds mean there's a little less solar energy available.	
If you are running your air conditioner, you need two pieces. If you are not, you only need one.	Pass objects in fits and starts – three at a time, and then a gap, then four, and then two, and so on.
Who has enough electricity? Who needs more?	Gather all objects back.

MIT ENVIRONMENTAL SOLUTIONS INITIATIVE

Today I Learned About The Electric Grid

Load-Balancing Game, cont'd

Phase 4

Narrator Script	Electric Utility Action
Let's fast forward. We have our wind and solar, but now we've learned how to store the extra electricity from when the sun is really shining, or the wind is really blowing.	Hold up first cup with extra objects.
We have hydroelectricity from dams, and nuclear power.	Hold up second cup with extra objects.
Our electricity needs are lower, too - even when it is hot, fewer buildings need air conditioning because of how they're designed. We use super-efficient lights, appliances, and machines. You only need one piece of electricity each.	Pass objects from the bucket and both cups at a steady pace.
Our electric grid is balanced, and we are using fewer fossil fuels, which means we are not adding to the carbon dioxide blanket.	Gather all objects back.

Wrap-Up Questions

- What are some of the challenges to balancing an electric grid?
- As we add more solar and wind energy to our electric mix, what technology will help balance the grid?
- Why is it important to make buildings and systems more efficient?
- What kinds of energy do you think make most of the electricity that we use in our community?

Today I Learned About The Electric Grid

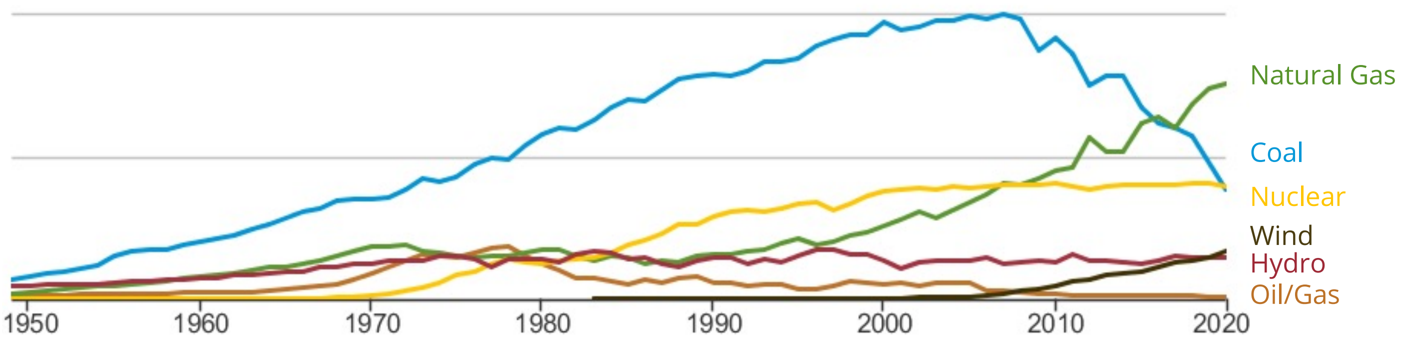
"Most people rate the creation of the electric power grid as probably the number one thing that happens in the 20th century.
We would build larger and larger electric power plants, and these were powered either by burning fossil fuels-- oil, gas, coal -- and using those to create steam in a boiler and the boiler steam would turn a generator -- an electric turbine -- and in the process would create the flow of electrons."
Harvey Michaels
TILclimate podcast: Today I Learned About The Electric Grid

A Brief History of the Electric Grid in the United States

1880s	Electric lights first used for public streets in Cleveland, OH. First electric power stations in New York City and San Francisco, burning coal. Inventions: Incandescent lightbulb, carbon filament, Alternating Current (AC), steam turbine generator, many other parts of electric generation and conduction.
1890s	Chicago World's Fair is lit with electric light for the first time. Power plants and lines are built for major cities.
1900s	Continued expansion of city electric grids. Inventions: electric vacuum cleaners, washing machines, electric cars.
1910s	Continued expansion of gas and oil turbines for city electricity. Inventions: electric air conditioners, refrigerators.
1920s	Electric utilities begin to interconnect between cities. Growth of hydroelectric plants/dams. Inventions: Traffic lights, camera flash bulbs, early televisions.
1930s	Rural Electrification Act gives loans to farmer cooperatives for electricity. Only 10% of rural America has electricity. Inventions: Clothes dryers, frozen foods.
1940s	Growth of farmer cooperatives developing electric grids throughout rural areas. Inventions: Color television, the Z3 computer, microwave ovens.
1950s	Expansion of electric appliances, etc. in the post-World-War economic boom. Over 80% of rural America has electricity. Inventions: Pocket-sized radios, color TV broadcast, AA batteries.

Today I Learned About The Electric Grid

Electricity Generation, 1950s to Present



A Warming Planet

As we burn fossil fuels like coal and natural gas to generate electricity, carbon dioxide (CO_2) is released into the atmosphere. CO_2 acts like a blanket, trapping heat and warming our air and ocean. Warmer air and warmer oceans are changing our climate, causing more extreme weather, sea level rise, and other disruptions all over the world.

Questions

- What surprised you about the history of electricity in the US?
- What do you notice about how we generate electricity in the US?

https://www.eia.gov/totalenergy/

Today I Learned About The Electric Grid

Electricity Use

Electricity use is not equal over the course of a day. Think about your own household or someone else's. On the next page:

1. In the left-hand (West Coast) column, quickly note how electricity is used on a normal day. Pay close attention to the times. One line is completed for you.
2. Think about who is home and what they are doing at these times.
3. Note whether the electricity use would be **high**, **medium**, or **low**.

Because of time zones, a similar family across the country on the East Coast would be doing the same actions, but three hours earlier.

4. In the right-hand (East Coast) column, note how electricity is used on a normal day. Pay close attention to the times. One line is completed for you.
5. Think about who is home and what they are doing at these times.
6. Note whether the electricity use would be **high**, **medium**, or **low**.

Questions

After completing the chart on the next page, answer the following questions:

1. What factors might change electricity use over the course of
    a. a week?
    b. a month?
    c. a year?
2. What factors might make electricity use different in northern vs southern states?
3. What other factors might make electricity use different in different households?

Today I Learned About The Electric Grid

Electricity Use, cont'd

Follow the instructions on the previous page to fill out this chart.

EST	Actions	Electricity use	PST	Actions	Electricity use
3-4 am			12-1 am		
6-7 am	*Waking up, getting ready for school and work.*	***High***	3-4 am	*Everyone asleep*	***Low***
9-10 am			6-7 am		
12-1 pm			9-10 am		
3-4 pm			12-1 pm		
6-7 pm			3-4 pm		
9-10 pm			6-7 pm		
12-1 am			9-10 pm		

Today I Learned About The Electric Grid

Electricity Use: Data Exploration

1. Visit the Energy Information Administration’s Hourly Electric Grid Monitor.

https://www.eia.gov/beta/electricity/gridmonitor/dashboard/electric_overview/US48/US48

2. Click the icon to get to the custom view.

3. Under Map Options and Date Range Type, select **Custom**. Enter any date you choose.

4. Under Map Data Type, select **Demand**. Under Change from prior hour, select **Percent**.

5. Below the map, click the to see the change in electricity demand over the course of the day. You can track the time of day above the map. Darker blue circles show utilities where customers are using less electricity than the hour before. Darker red circles show utilities where customers are using more electricity than the hour before.

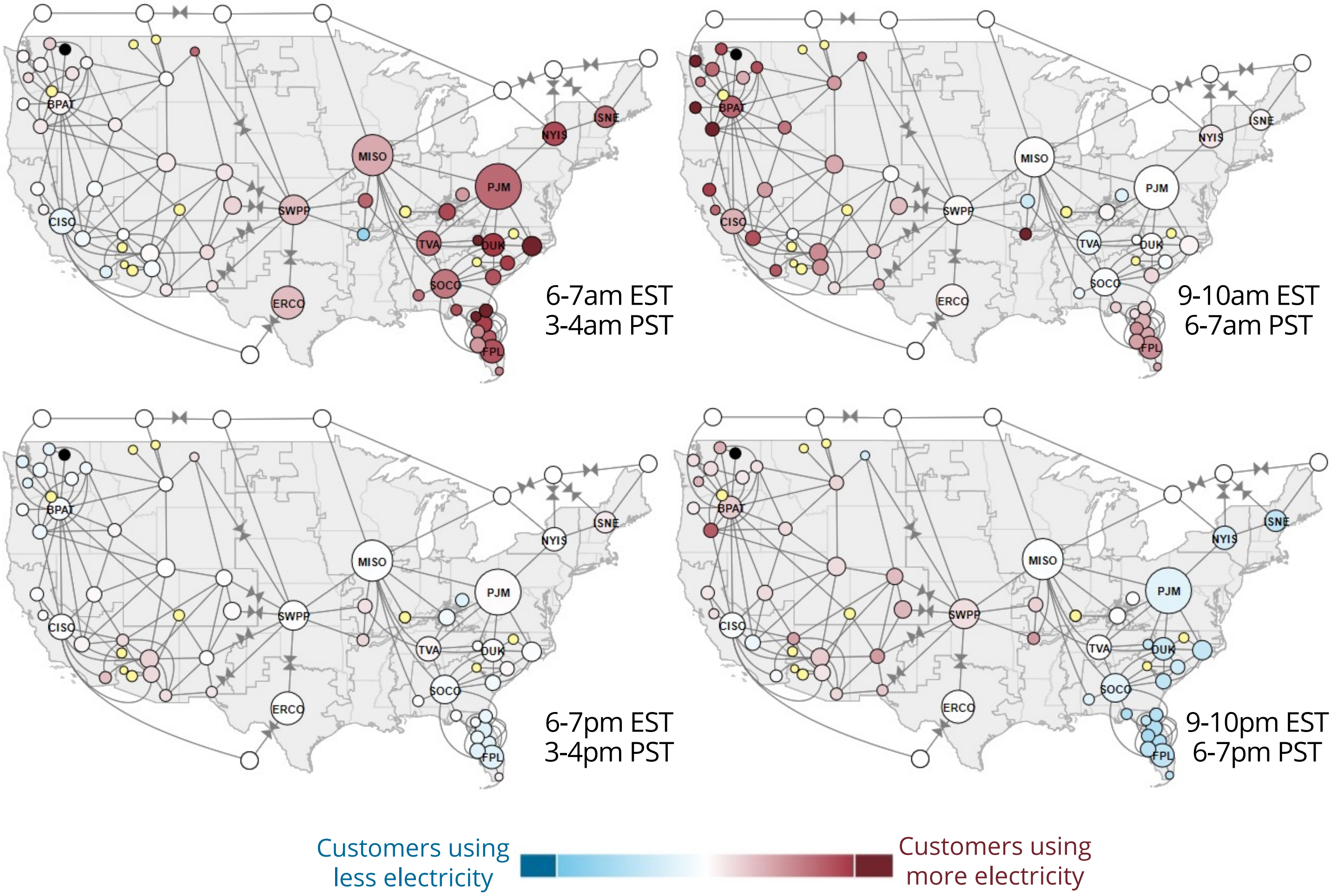
6. Below the map, click the slider to move to the specific hours from your timeline on Page 1. The map displays data for the hour ending at the time shown, so the data for the hour 3-4am can be found in the 4am map.

Questions

1. Do these maps line up with your predictions? Why or why not?
2. What happens when you look at a different time of year? Are there any surprises?
3. What other questions could you explore with this tool?

Today I Learned About The Electric Grid

Electricity Use: Map Exploration



Questions

1. Do these maps line up with your predictions? Why or why not?
2. These maps are from March. What would you expect if you looked at data from a different time of year?
3. What other questions could you explore with this tool?

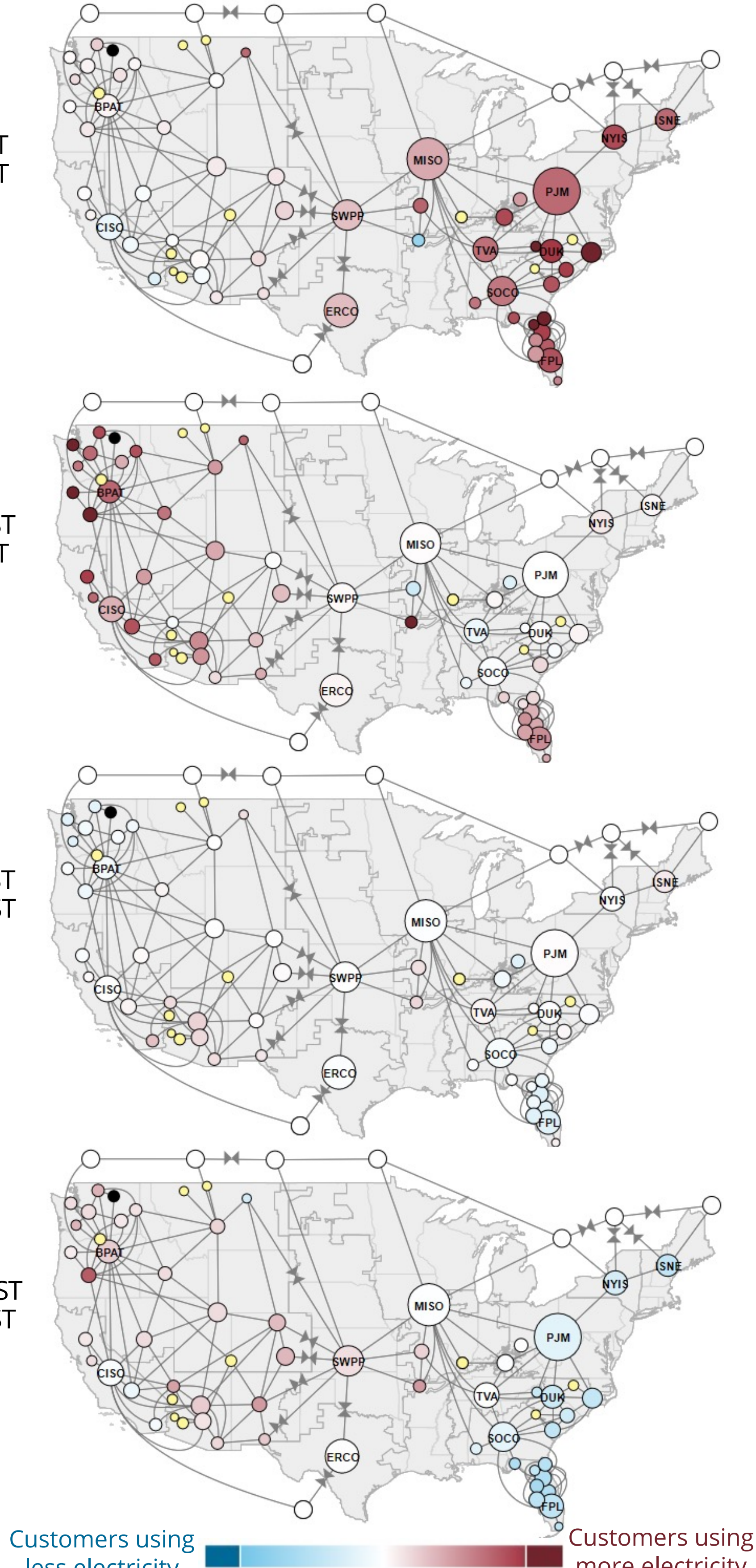
Data from March 15, 2016 https://www.eia.gov/beta/electricity/gridmonitor/dashboard/electric_overview/US48/US48

6-7am EST
3-4am PST

9-10am EST
6-7am PST

6-7pm EST
3-4pm PST

9-10pm EST
6-7pm PST



Data from March 15, 2016 https://www.eia.gov/beta/electricity/gridmonitor/dashboard/electric_overview/US48/US48

Today I Learned About The Electric Grid

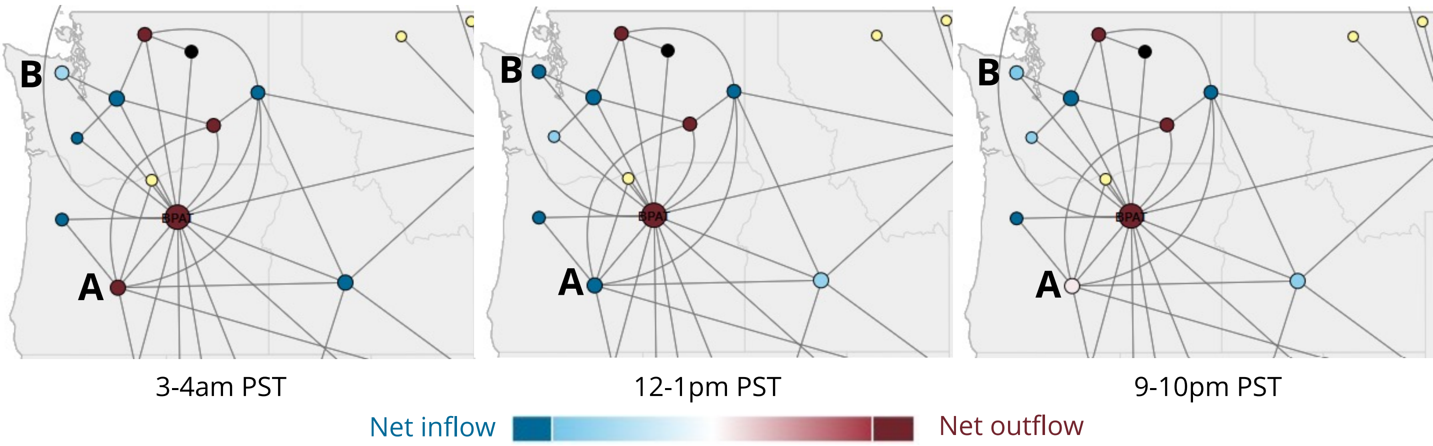
“The complexity of the grid is that there needs to be exactly the right amount of power put into the wires to serve all the instantaneous needs of all the people on the system. It doesn't really have the ability to store electricity in the wires themselves. So the electric company has to create a system so the amount of power that's being injected into the wires is just about exactly equal to the amount of electricity that's being taken out of the wires.”

Harvey Michaels, MIT Sloan School of Management
TILclimate podcast: Today I Learned About The Electric Grid

Supply & Demand

Balancing the amount of electricity running through the wires is a big job. If demand (the amount of electricity used in an area) is higher than supply (the amount of electricity available in the wires) people experience flickering lights, brownouts, and blackouts. If demand is lower than supply, utilities dump the excess electricity, which is wasteful and expensive.

In the following three maps of the Pacific Northwest region, the utilities are trading electricity in order to meet demand. Utilities with a net inflow (blue) are having to get electricity from a neighbor to meet demand. Utilities with a net outflow (red) are making more than enough electricity to meet demand and are sending the excess to a neighbor.

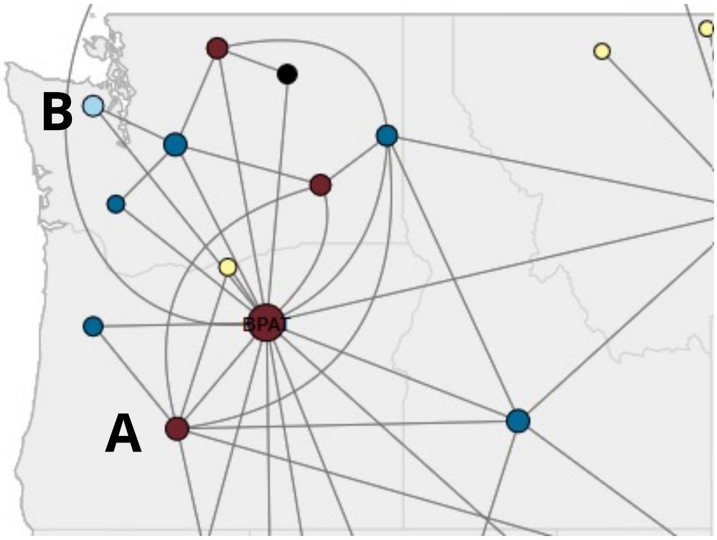


Questions

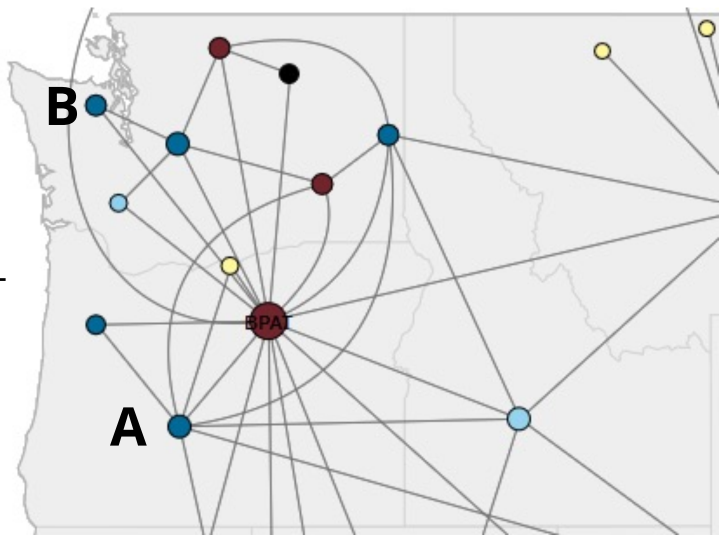
1. What is happening at each of these utilities over the course of the day?
2. If you were the manager of each of these utilities, would you change how you are making electricity? Why or why not?

https://www.eia.gov/beta/electricity/gridmonitor/dashboard/electric_overview/US48/US48

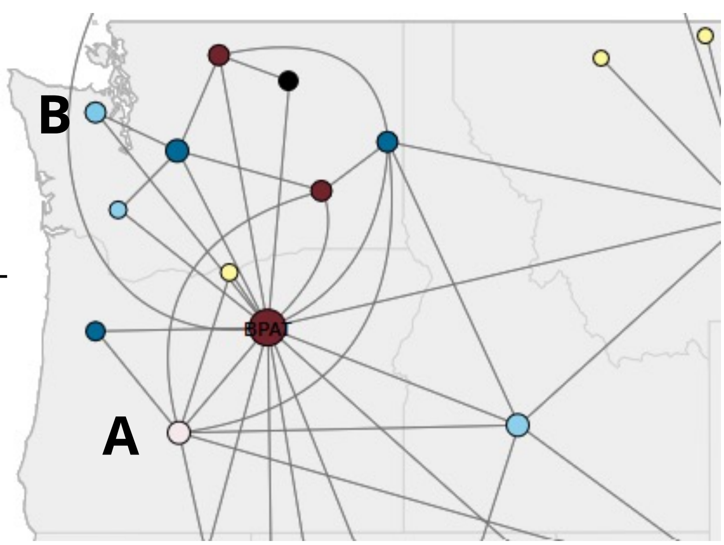
3-4am PST



12-1pm PST



9-10pm PST



Net inflow Net outflow

https://www.eia.gov/beta/electricity/gridmonitor/dashboard/electric_overview/US48/US48

Today I Learned About The Electric Grid

My Electric Grid: Shape

1. Visit https://atlas.eia.gov/pages/energy-maps
2. Click **Electricity**.
3. Click the **Layer Stack** icon and toggle all the layers off (from to) except for **Pipelines** and **Transmissions**.
4. Click the arrow next to **Pipelines and Transmission** and toggle on **Electric Power Transmission Lines** and **Electric Substations**. Only these two options should be toggled on ( ) Click the double arrow to the right of the layer box to minimize the layer stack.
5. Zoom the map to an area you are familiar with. If you zoom too far in, you may notice that the Electric Substations (pale purple circles) disappear.
6. Click the **Legend** to see what the various colors and weights of lines mean.

Questions

1. What do you notice first about how the electric grid is shaped in your area?
2. Is the grid evenly distributed? Why do you think this may be?

(It may help to toggle the basemap in the lower right-hand corner to a satellite image.)

3. The system of substations, high-power lines, and step-down lines grew over time as electricity use grew from cities in the 1880s to rural areas in the 1930s, and then as suburban populations grew in the 1940s through the 1990s.

If you were to design an electric grid now, instead of growing it over more than a century, what factors would you consider?

Solutions

Infrastructure experts are working to make the electric grid smarter. Watch the videos at https://www.smartgrid.gov/the_smart_grid/ to learn more about how the grid is changing to meet 21st century demands.

MIT researchers are inventing new ways to think about our electric grid at https://energy.mit.edu/area/power-distribution-energy-storage/

Today I Learned About The Electric Grid

My Electric Grid: Source

For this investigation, you may choose the region you live in or another region of the US.

1. Visit https://www.epa.gov/egrid/data-explorer

2. On the map, determine which eGRID subregion your focus area is in. Write its 4-letter code here:

3. In the dropdown menu after “I want to explore” select **resource mix.**

4. Select the subregion you are focusing on. For each fuel type, the chart to the right shows the US average percentage of that resource and the percent that is used in your subregion.

Questions

1. What do you notice first about how the different subregions are generating electricity?
2. How far off from the national average is each of your subregion’s fuel sources?
3. Given the options in the drop-down menus after “I want to explore,” what questions can you investigate about the electric grid in the US?
4. Investigate one of the questions you defined. How would you share what you learned with a friend or family member?