

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. |

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Load-Balancing Game, cont'd

Phase 2

Narrator Script

Today it is very hot. You need two times the electricity because you are running the air conditioner.

Our electric grid has to work a lot harder to stay balanced today. It is managing to produce enough electricity.

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.

Electric Utility Action

Pass objects at a faster pace, such that everyone gets two items, and no one has to wait too long.

Gather all objects back.

Phase 3

Narrator Script

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.

Who has enough electricity? Who needs more?

Electric Utility Action

Pass objects in fits and starts – three at a time, and then a gap, then four, and then two, and so on.

Gather all objects back.

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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?

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“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

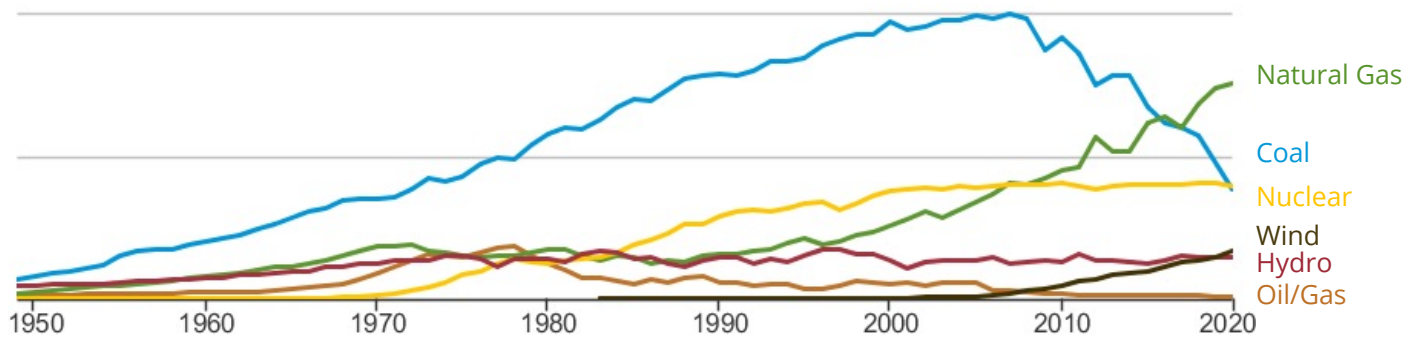
TILclimate podcast: Today I Learned About The Electric Grid

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.

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Electricity Generation, 1950s to Present



A Warming Planet

As we burn fossil fuels like coal and natural gas to generate electricity, carbon dioxide (CO₂) is released into the atmosphere. CO₂ 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?

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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?

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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 | <i>Waking up, getting ready for school and work.</i> | High | 3-4 am | <i>Everyone asleep</i> | 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 | | |

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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.

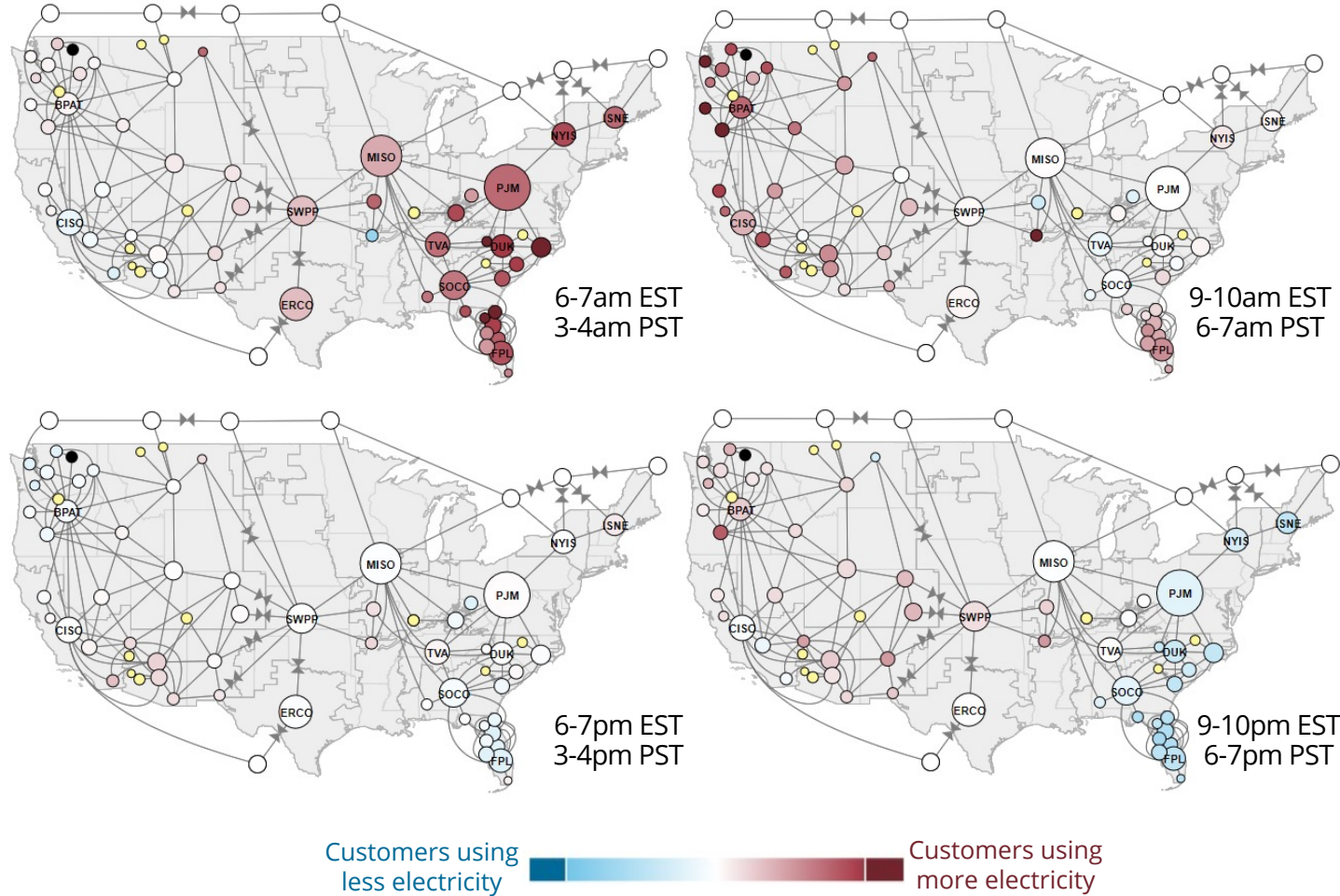


Questions

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?

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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

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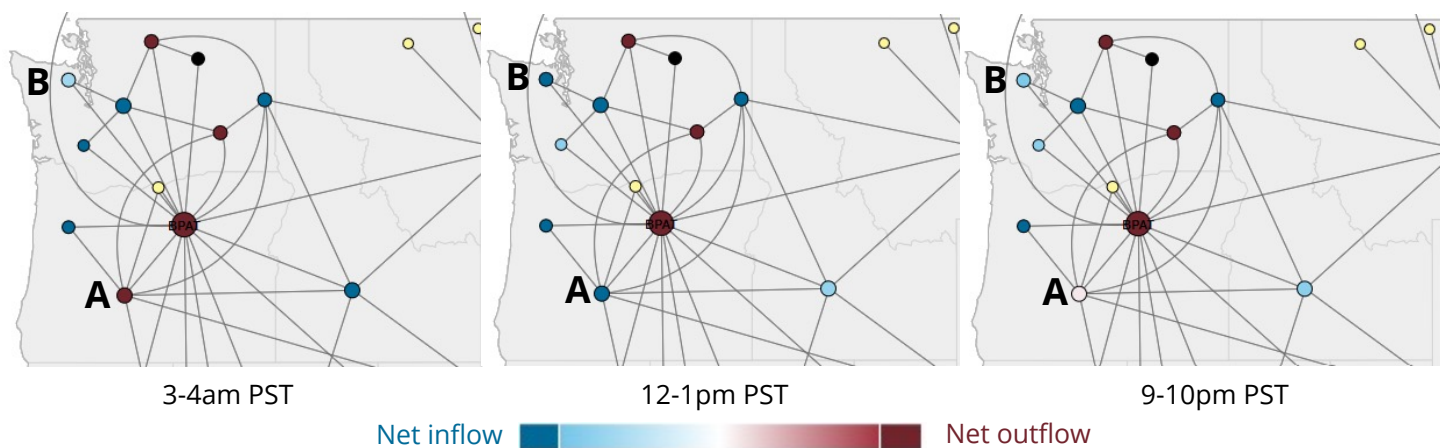
"The complexity of the grid is that there needs to be exactly the right amount of power put into the wires to serve all the instantaneous needs of all the people on the system. It doesn't really have the ability to store electricity in the wires themselves. So the electric company has to create a system 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?

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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/>

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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?