

Data, Accessibility, and Tools



Frank Elavsky



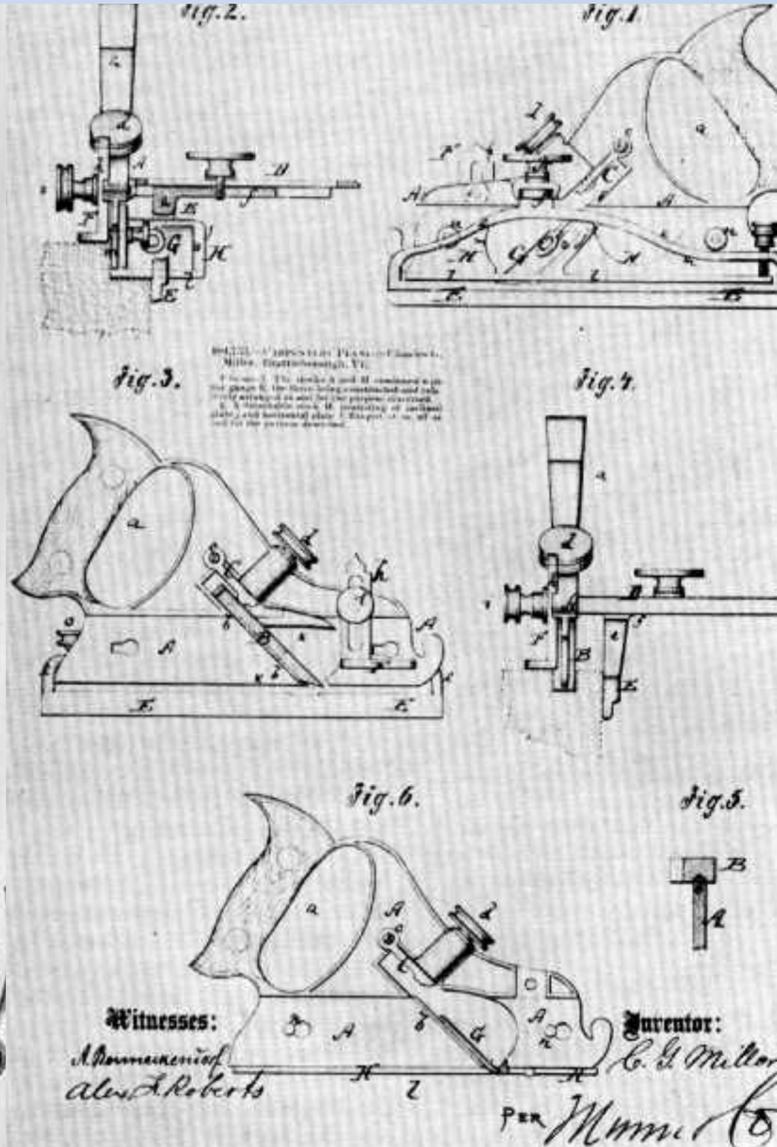
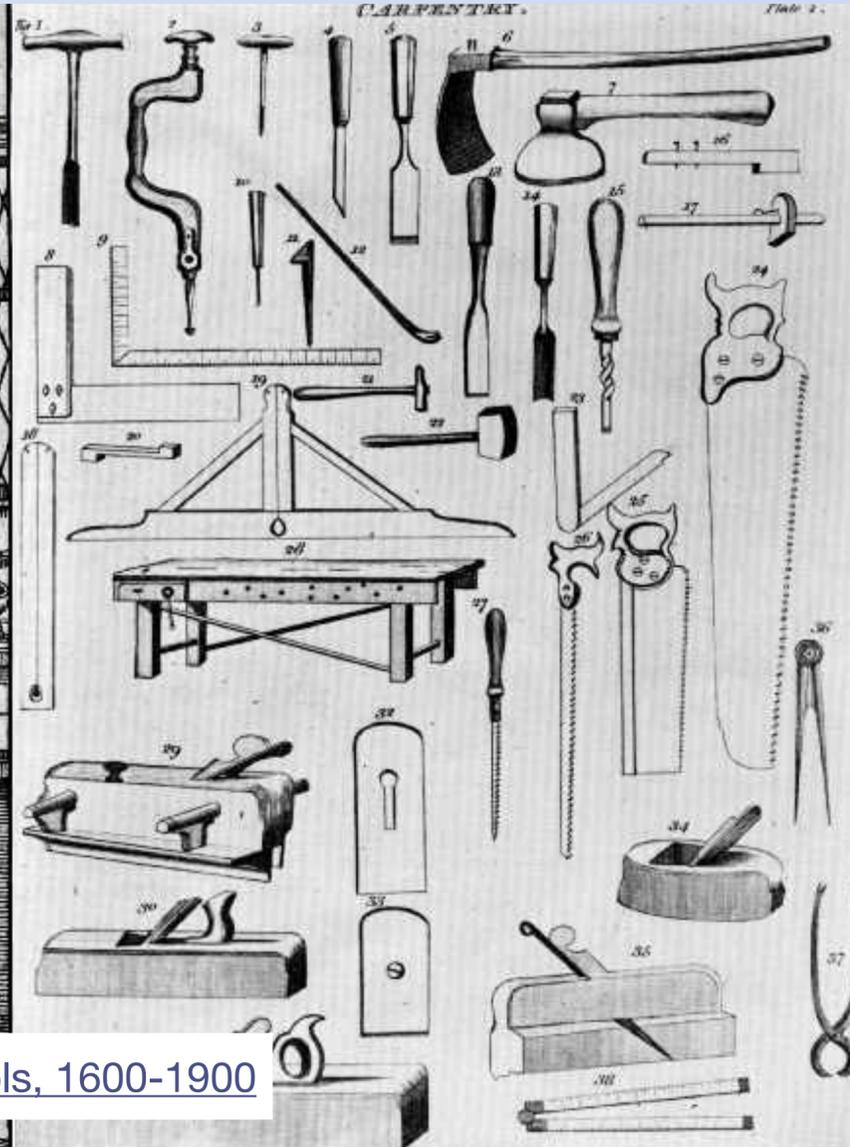
hcii.cmu.edu, axle-lab.com, dig.cmu.edu





Credit: Jeff Kubina, [Wikimedia](#)

Human-tool interaction and the role of the tool-maker



Woodworking Tools, 1600-1900

People with disabilities deserve to:

Participate in politics

PRESIDENTIAL RESULTS

Joe Biden wins election to be the 46th US President

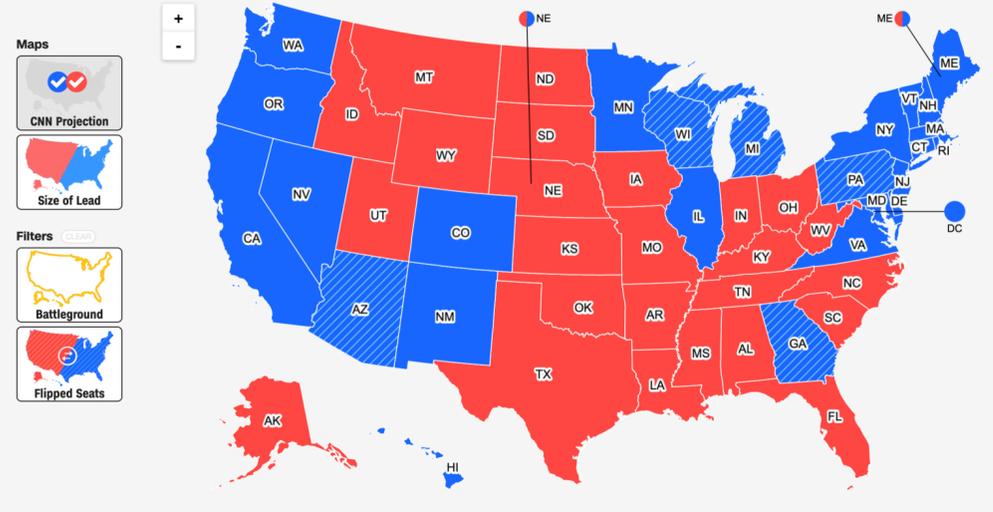
Pennsylvania's 20 electoral votes put native son Joe Biden above the 270 needed to become the 46th President of the United States. Born in Scranton, the former vice president and longtime Delaware senator defeated Donald Trump, the first President to lose a reelection bid since George H.W. Bush in 1992.



CNN Projection

Updated 10:44 a.m. ET, May, 5

Win Flip Biden Win Flip Trump

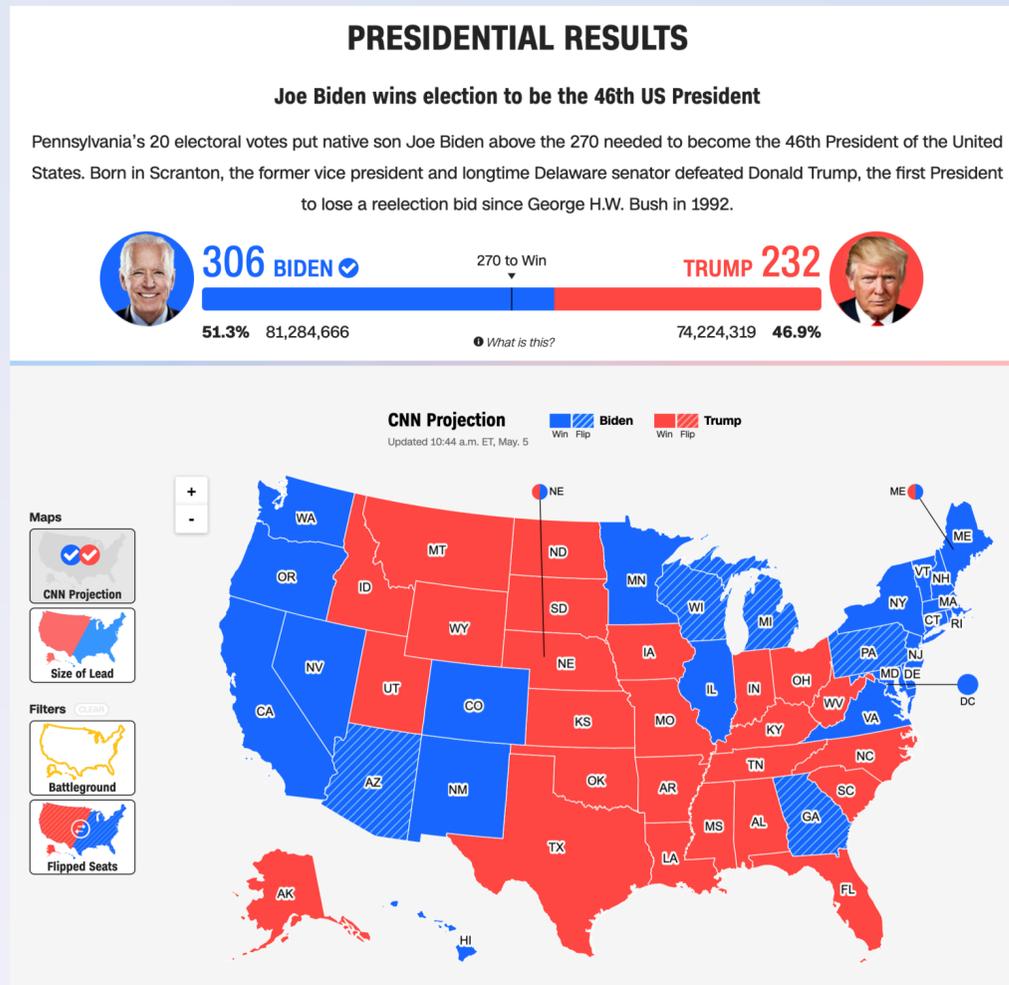


Credit: [CNN](#)

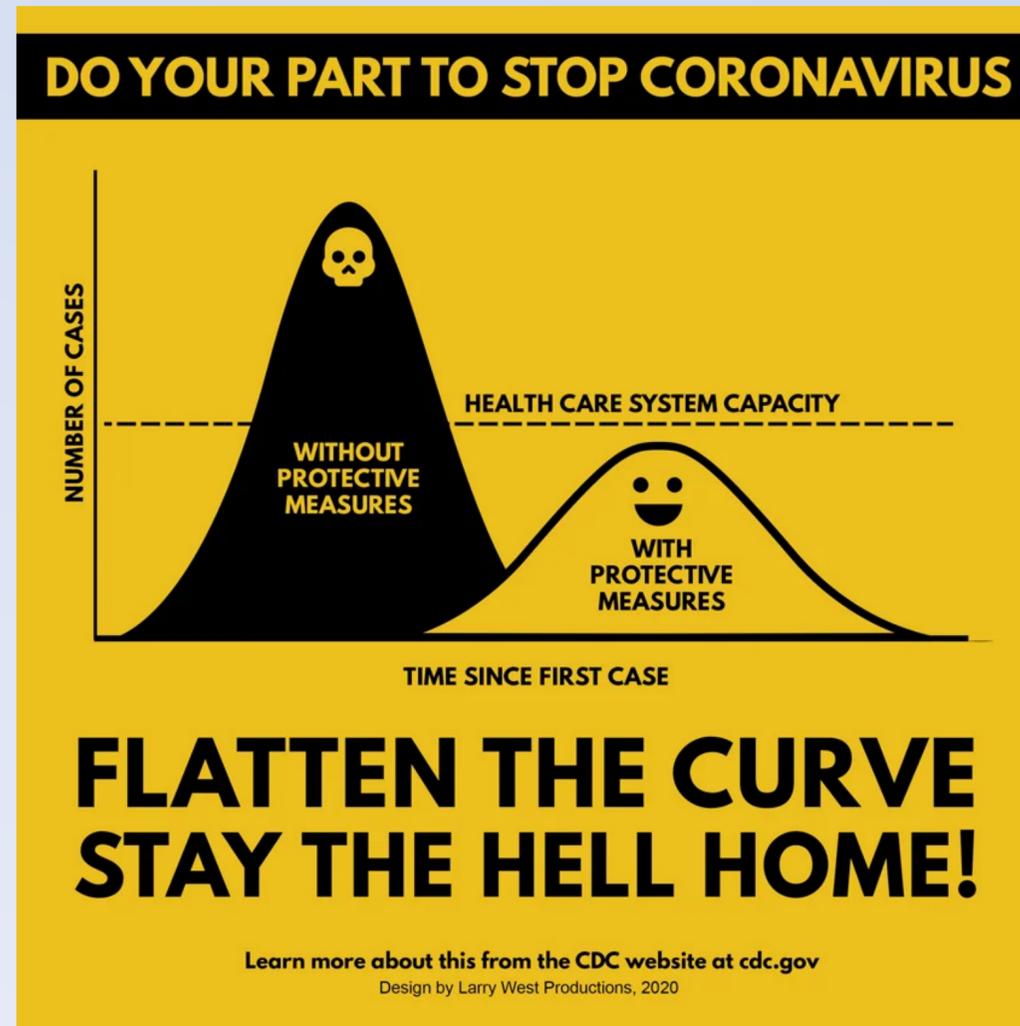
People with disabilities deserve to:

Participate in politics

Make informed decisions



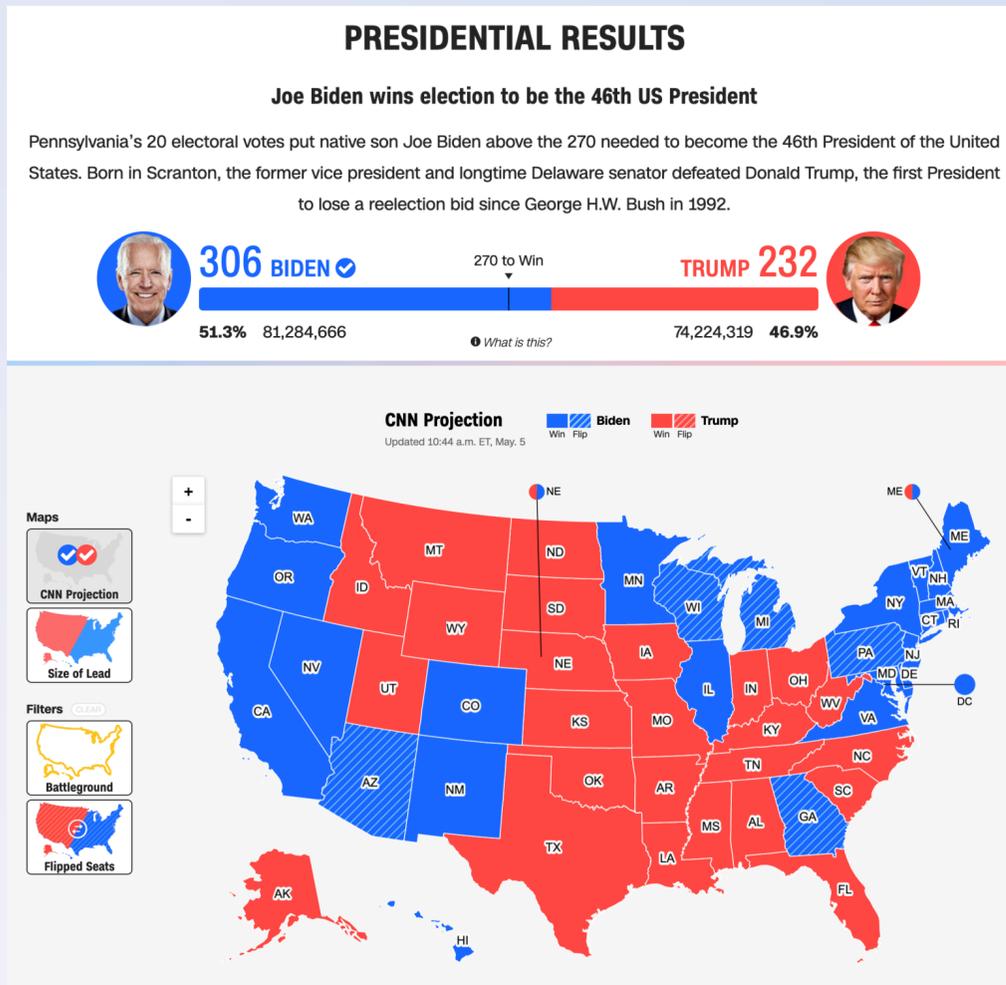
Credit: [CNN](#)



Credit: [Reddit](#)

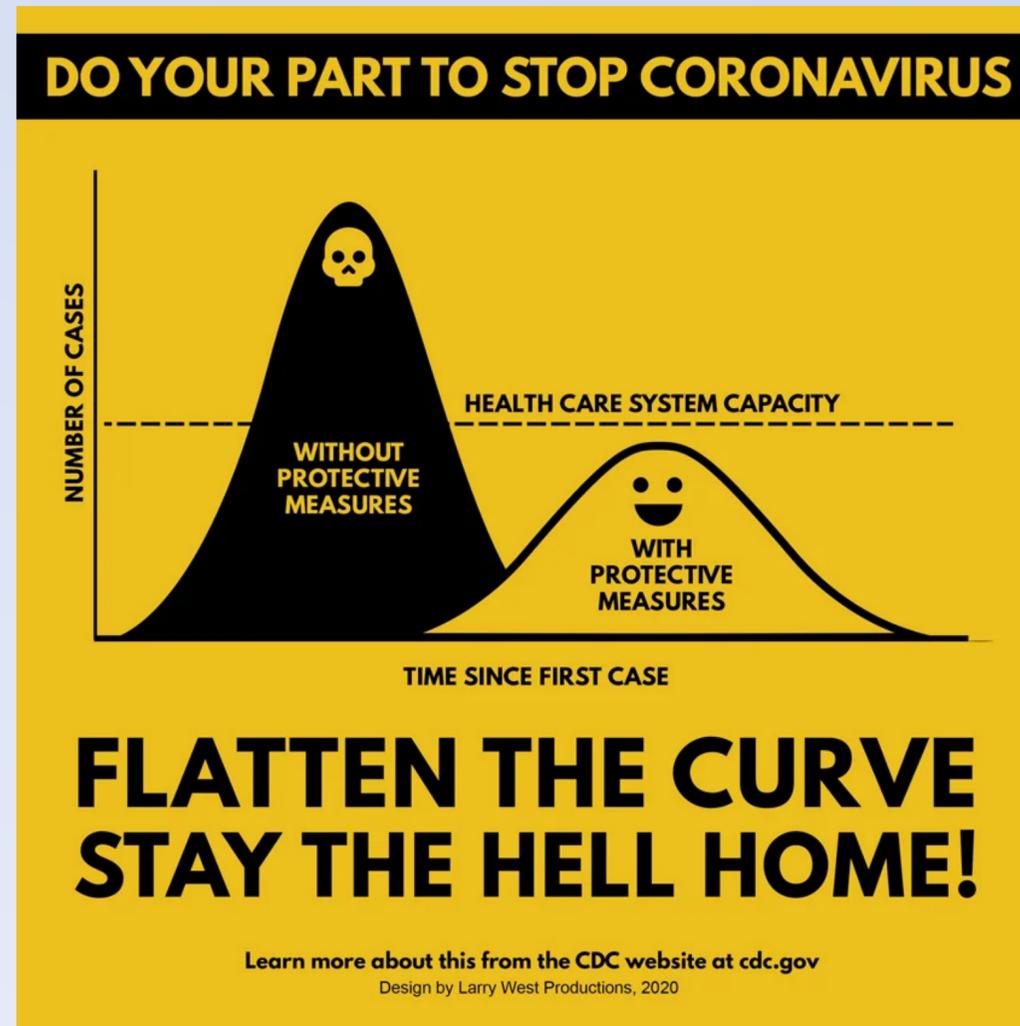
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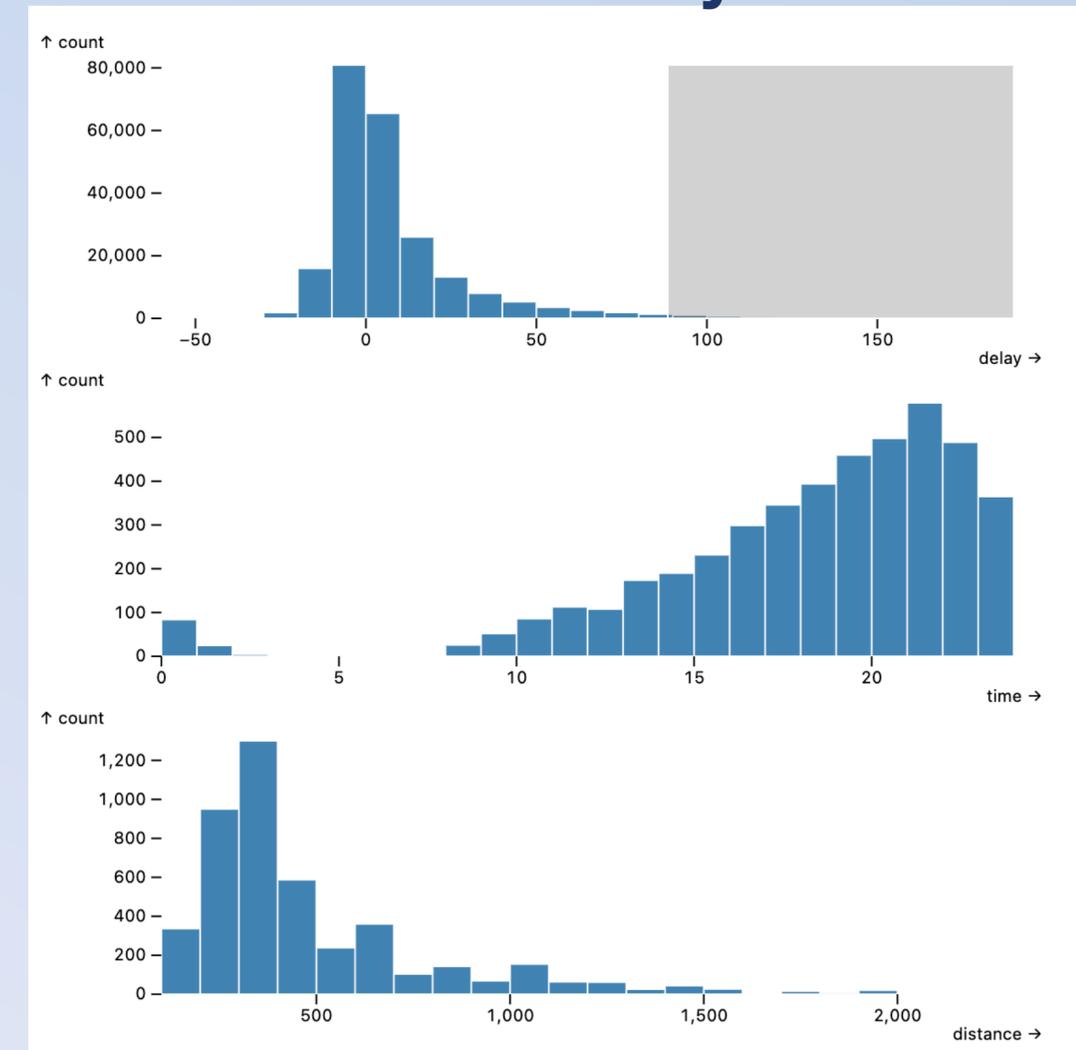
Credit: [CNN](#)

Make informed decisions



Credit: [Reddit](#)

Analyze data quickly and efficiently



Credit: [Our research](#)

Tools serve the intentions of their creators

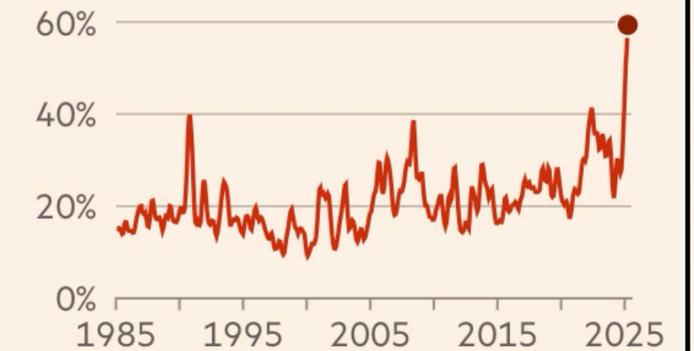
US consumers are rapidly souring on Trump's economic plan

Share of adults who...

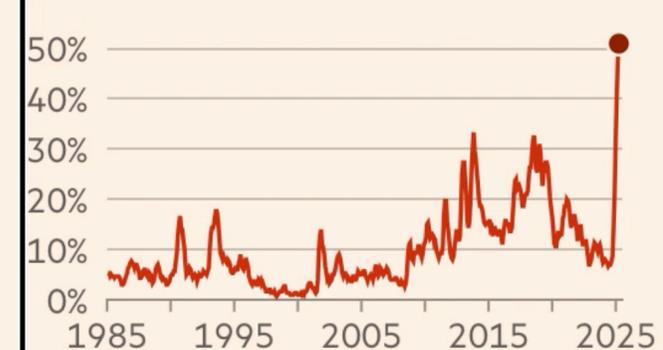
Have a negative opinion of government's economic policy



Expect business conditions to worsen over next year



Have heard unfavourable business news coverage of government



Expect their income will grow faster than inflation in next 5 years



Source: [University of Michigan consumer sentiment survey](#).

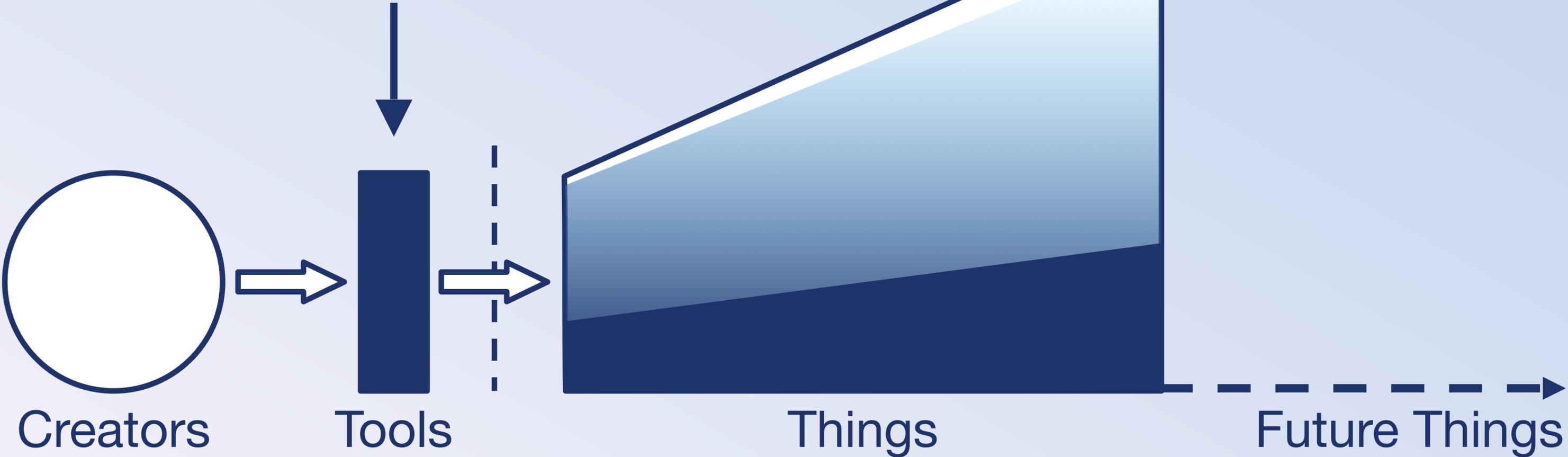
FT graphic: John Burn-Murdoch / @jburnmurdoch

©FT

✕ You are currently on a frame. To enter the web area, press Control-Option-Shift-Down Arrow.

Republican. No need to take that from me: it's a well-evidenced

Can better tools reduce inaccessibility?



Data, Accessibility, and Tools

Tools for *explanation*

Tools for *exploration*

Tools for *scale*

Tools for *thinking*

Tools for *complexity*

Tools for *possibility*



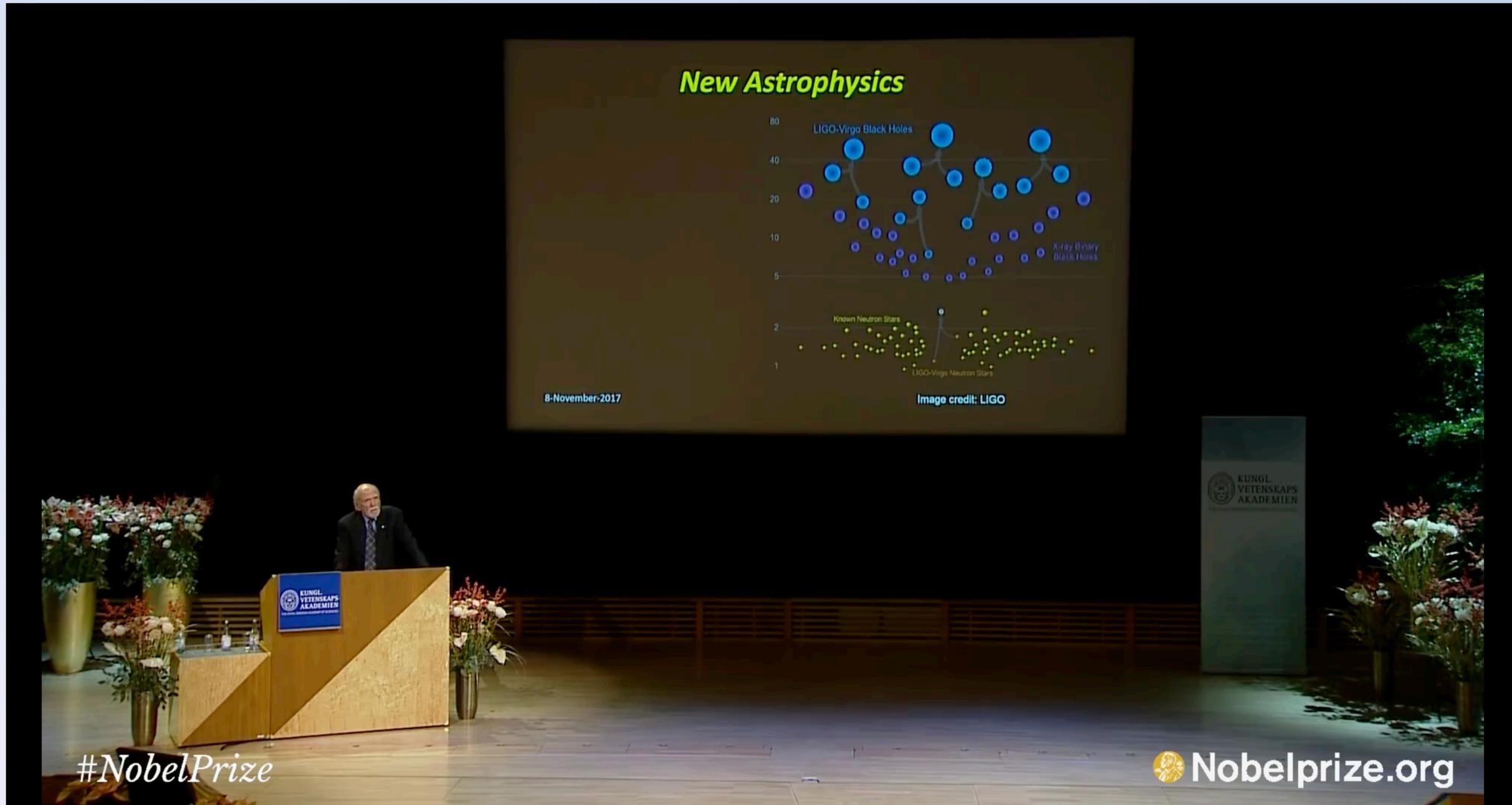
Industry work



PhD research

Tools for *explanation*:
Empower people to
communicate, teach,
and captivate





[Source](#)

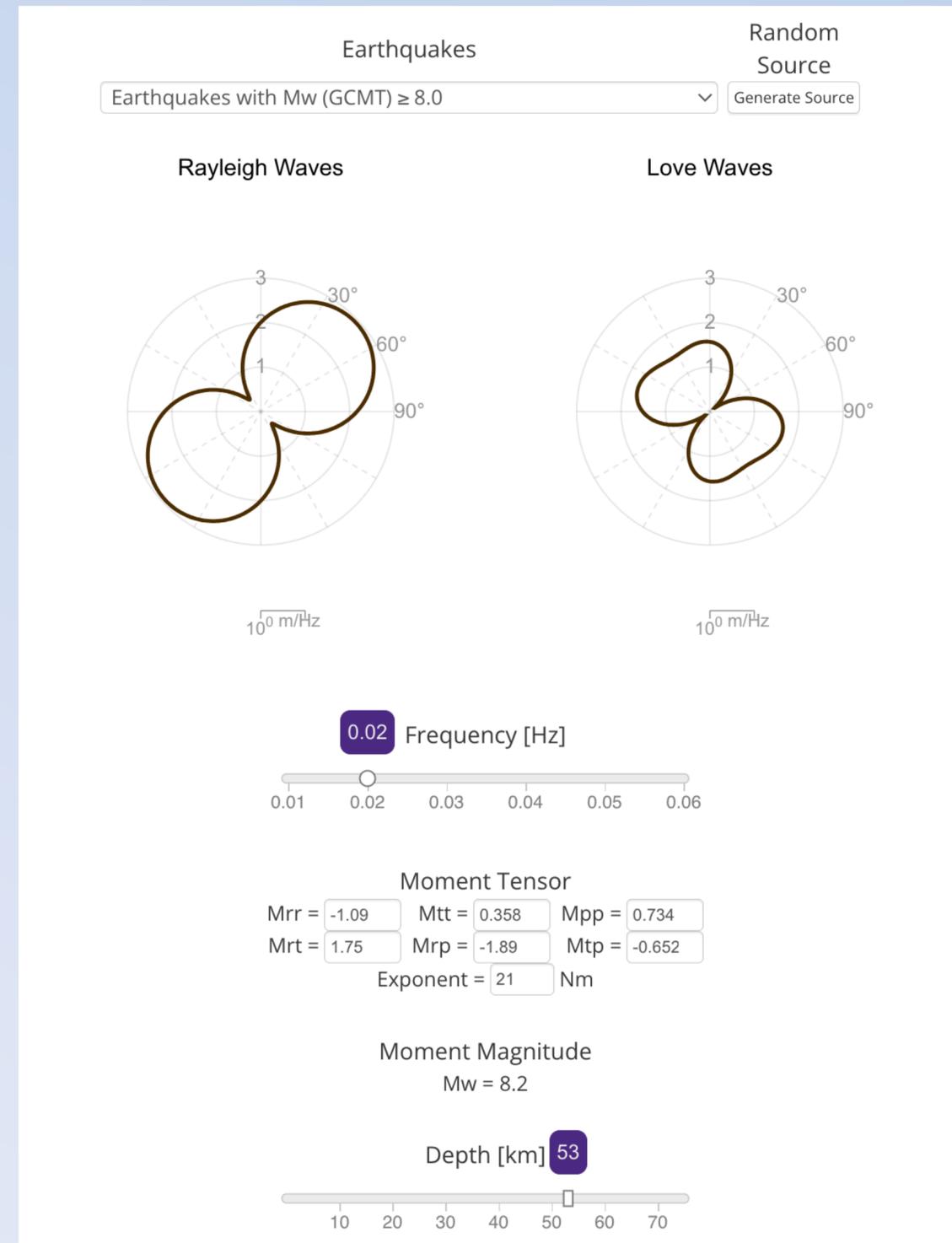
Barish, B. C. (2018). Nobel Lecture: LIGO and gravitational waves II. *Reviews of Modern Physics*, 90(4). [doi:10.1103/revmodphys.90.040502](https://doi.org/10.1103/revmodphys.90.040502)

Tools for *exploration*:
Provide people with
methods for discovery



Arbitrary (and data-driven) surface wave model visualization for seismologists

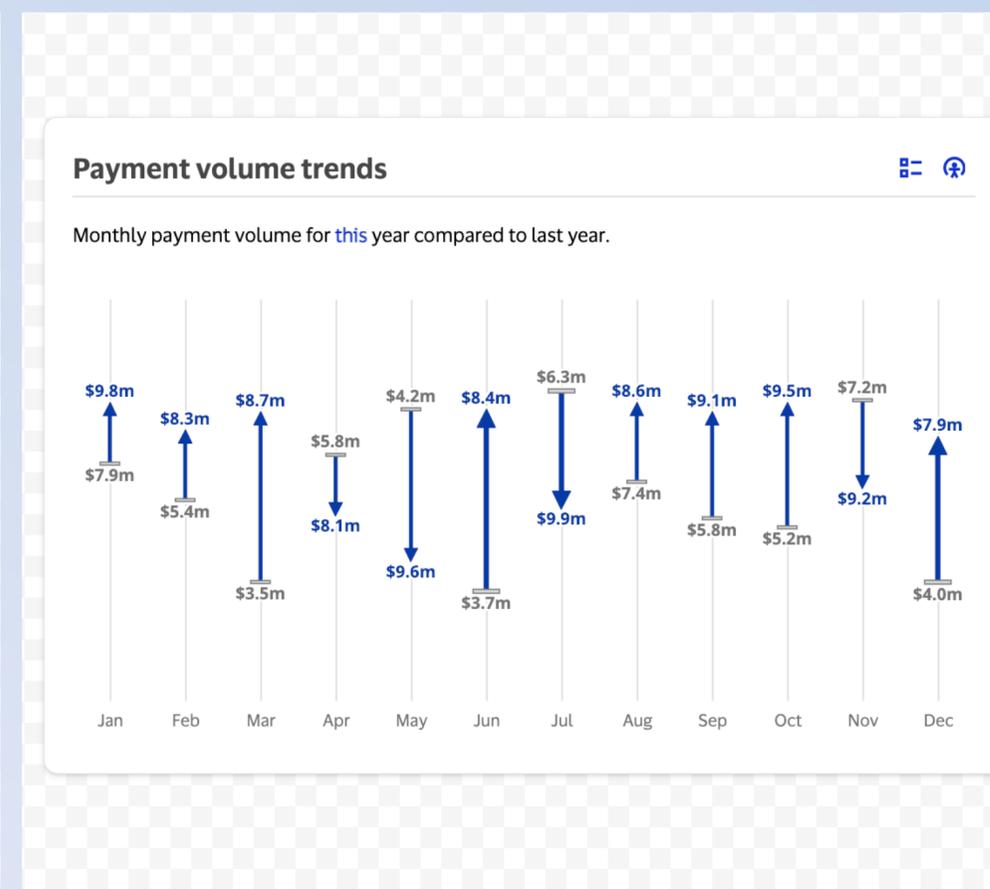
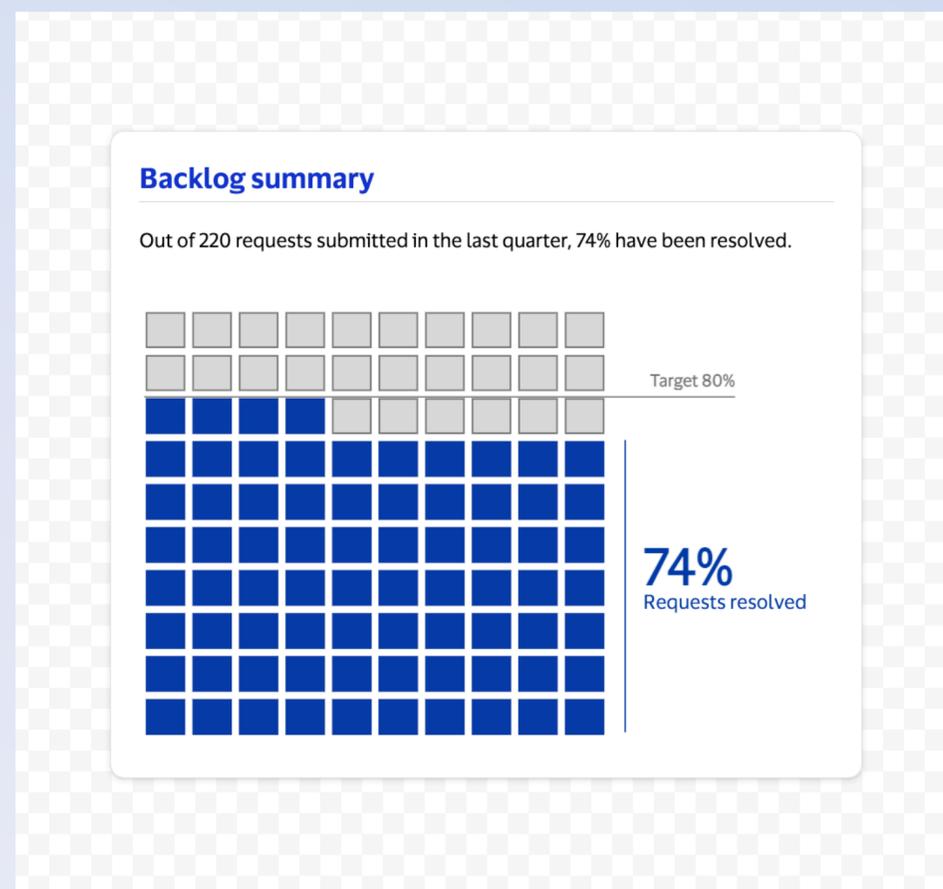
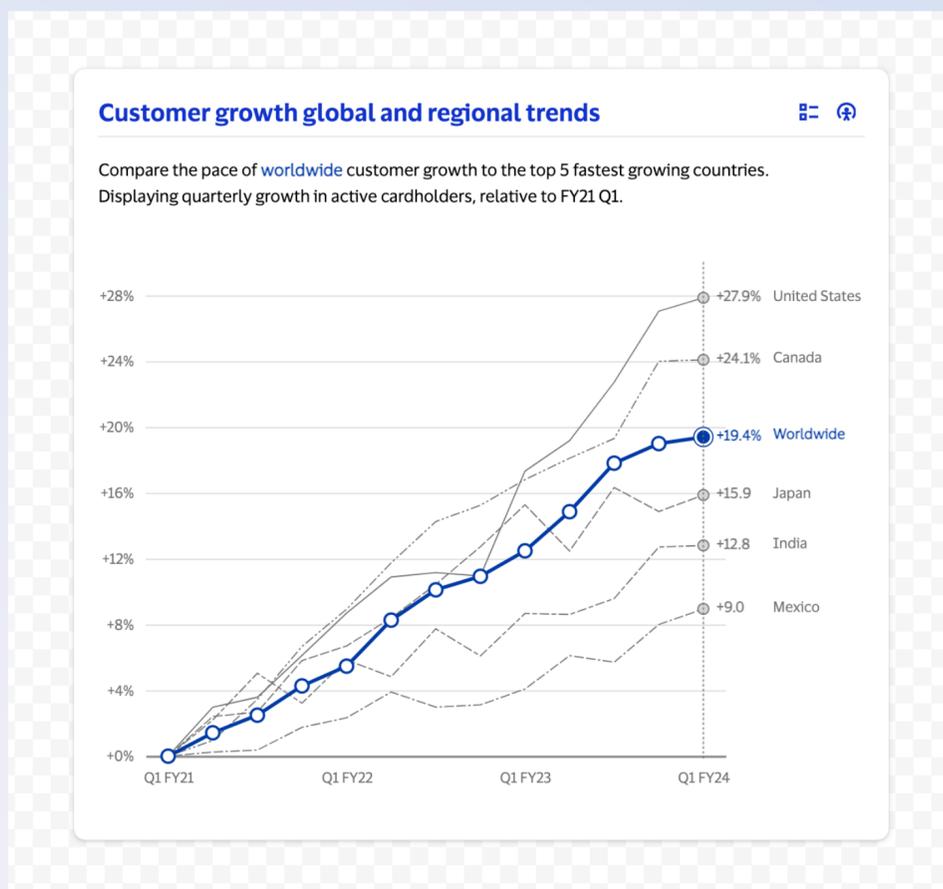
Rösler, B., and S. van der Lee (2020). Using Seismic Source Parameters to Model Frequency-Dependent Surface-Wave Radiation Patterns. *Seismol. Res. Lett.* 91, 992–1002, [doi:10.1785/0220190128](https://doi.org/10.1785/0220190128).



Tools for *scale*:
Drive people to build
better and faster



Visa Chart Components and “out of the box” accessibility

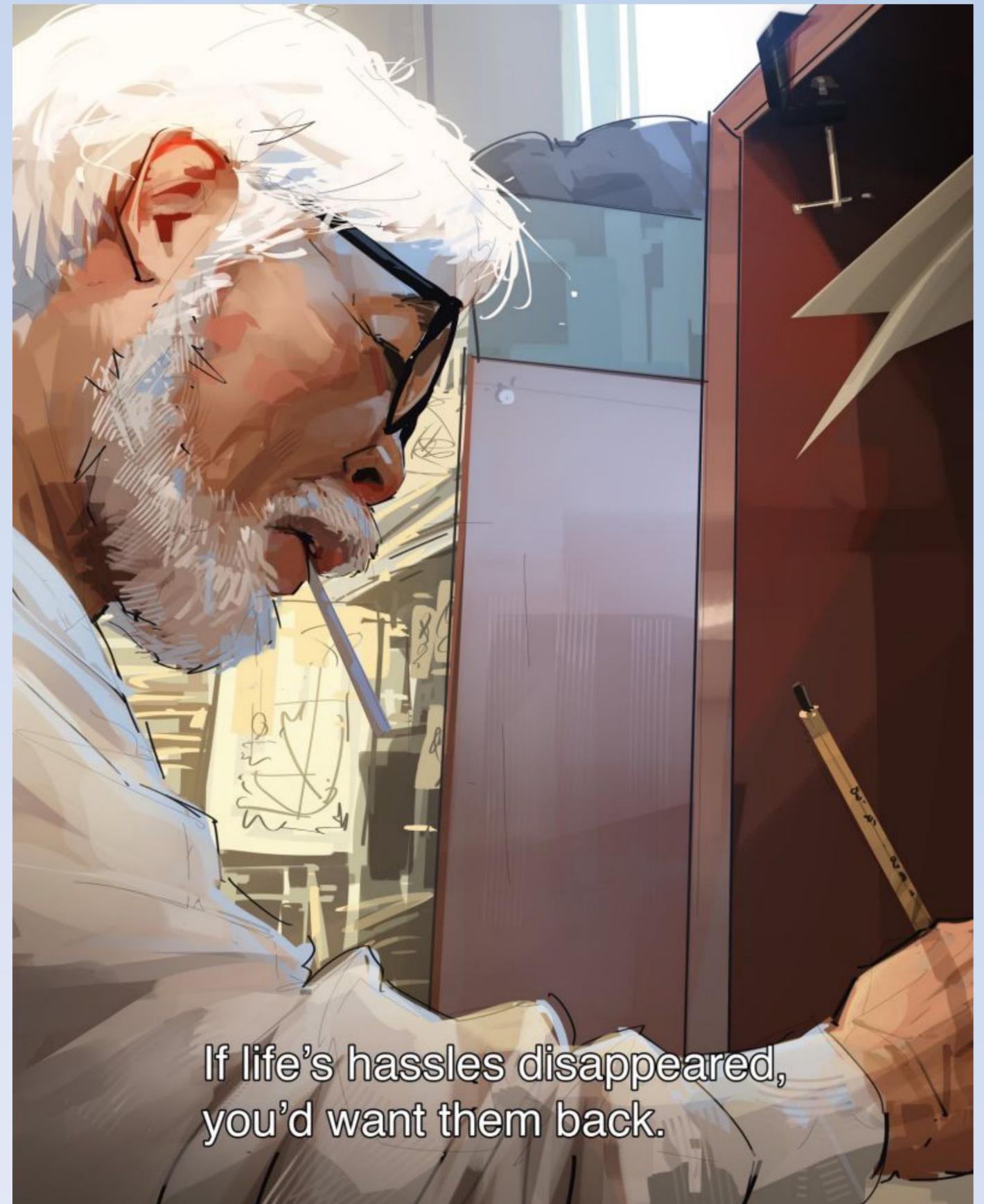


Automatic accessibility validation

▸ bar-chart-1 has strong accessibility recommendations	bar-chart.entry.js:49478
▼ bar-chart-2 has accessibility warnings and other messages	bar-chart.entry.js:49497
⚠ ▸ longDescription: Either accessibility.longDescription or accessibility.contextExplanation is required	bar-chart.entry.js:49499
⚠ ▸ executiveSummary: Either accessibility.purpose or accessibility.executiveSummary is required	bar-chart.entry.js:49499
⚠ ▸ elementsAreInterface: elementsAreInterface must be a `boolean` type, but the final value was: `null`. If "null" is intended as an empty value be sure to mark the schema as `.nullable()`	bar-chart.entry.js:49499
longDescription: Either accessibility.longDescription or accessibility.contextExplanation should have minimum 40 characters and a combined length between 40 and 500 characters	bar-chart.entry.js:49481
executiveSummary: Either accessibility.purpose or accessibility.executiveSummary should have minimum 40 characters and a combined length between 40 and 250 characters	bar-chart.entry.js:49481
statisticalNotes: accessibility.statisticalNotes should have length between 40 and 250 characters	bar-chart.entry.js:49481
structureNotes: accessibility.structureNotes should have length between 40 and 250 characters	bar-chart.entry.js:49481

**“If life’s hassles
disappeared, you’d
want them back”
- Hiyao Miyazaki**

Art credit: [Sam Yang](#)



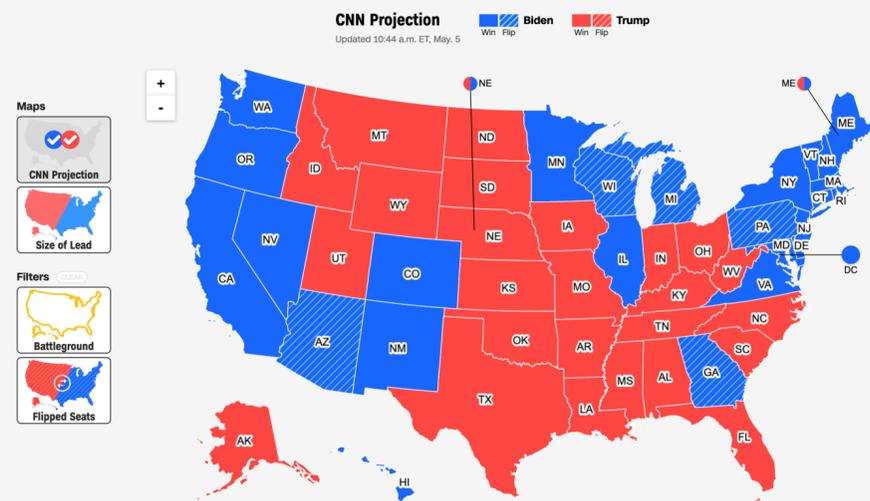
Tools for *thinking*:
Help people to
evaluate critically



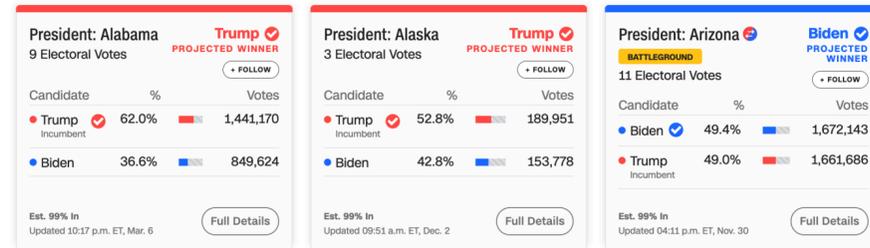
PRESIDENTIAL RESULTS

Joe Biden wins election to be the 46th US President

Pennsylvania's 20 electoral votes put native son Joe Biden above the 270 needed to become the 46th President of the United States. Born in Scranton, the former vice president and longtime Delaware senator defeated Donald Trump, the first President to lose a reelection bid since George H.W. Bush in 1992.



STATE RESULTS



Show More States

How do you find and evaluate access barriers in interactive visualizations?

Chartability is a workbook of tests, tools, and principles

How do you use Chartability?

There are a lot of different ways to perform an audit, and so there are also many different ways to use Chartability. Sometimes an audit is as casual as checking your work while you do it. And other times it is a big affair that involves teams of specialists and lawyers.

Realistically, while a highly trained auditor may be able to casually evaluate an artifact in as little as 30 minutes or even hold heuristics in mind as they are doing their own creative work, those new to auditing may take anywhere between 2 and 8 hours to complete a full pass of Chartability. Professional audits, which can take weeks or months, often include multiple auditors and provide rigorous documentation and detailed recommendations for remediation, typically in the form of a report. Chartability is meant to serve both quick pass and deep dive styles of audits, so users are expected to leverage it as they see fit.

Below we give an example of what might be a fast pass audit, using Chartability, in 5 steps. This isn't super thorough, but a good way to quickly check a handful of access barriers quickly.

1. Visual Testing

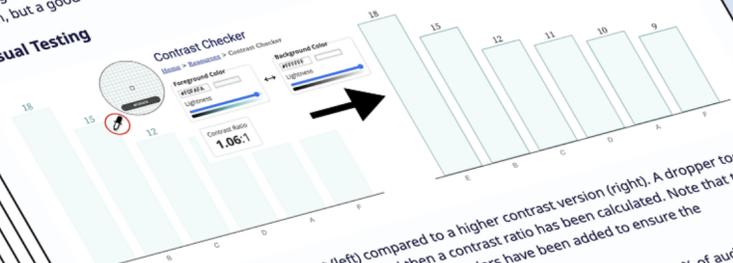
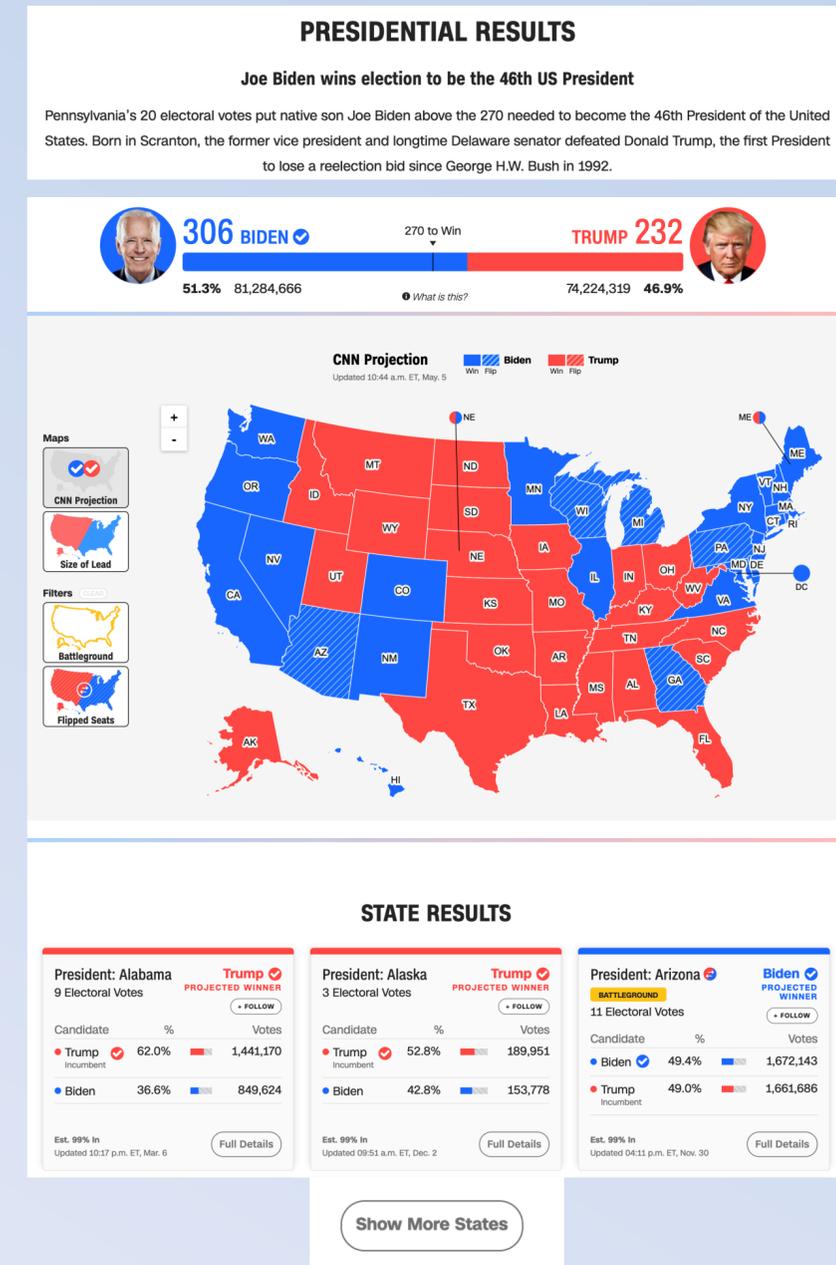


Figure 1: A low contrast chart (left) compared to a higher contrast version (right). A dropper tool is extracting the fill color of the bar and then a contrast ratio has been calculated. Note that the visualization passes contrast tests.

Checking for contrast is the most common critical failure across all of our audits (88% of audits failed this heuristic). In order to evaluate contrast, often a combination of automatic (code-driven) and manual tooling is performed. When manually auditing, practitioners typically use a dropper and a contrast calculator (Figure 1). Contrast is measured by finding adjacent colors that are intended to convey meaning or boundaries, and finding a ratio between them. Standards require a different minimum contrast for text (4.5:1) than geometries like marks in a chart (3:1). Most auditors find this to be one of the easiest tasks to perform, but techniques can be tricky to handle. Testing for contrast accomplishes 3 different heuristics in Chartability: ensuring text/geometries have contrast, interactive states for elements have enough contrast change, and the keyboard focus indicator is easy to distinguish.



F. Elavsky, C. Bennett, and D. Moritz, "How accessible is my visualization? Evaluating visualization accessibility with *Chartability*," Computer Graphics Forum, 2022.

Chartability is used in:

15+ Policy orgs and governments worldwide

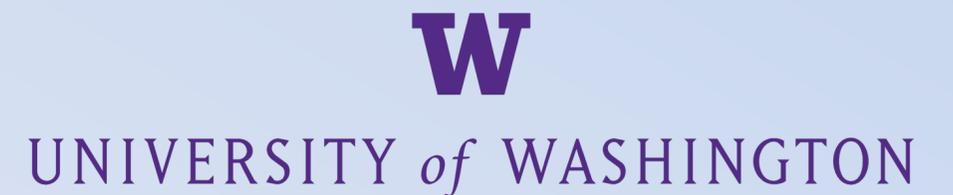


150+ Tech, news, and non-profit companies/orgs



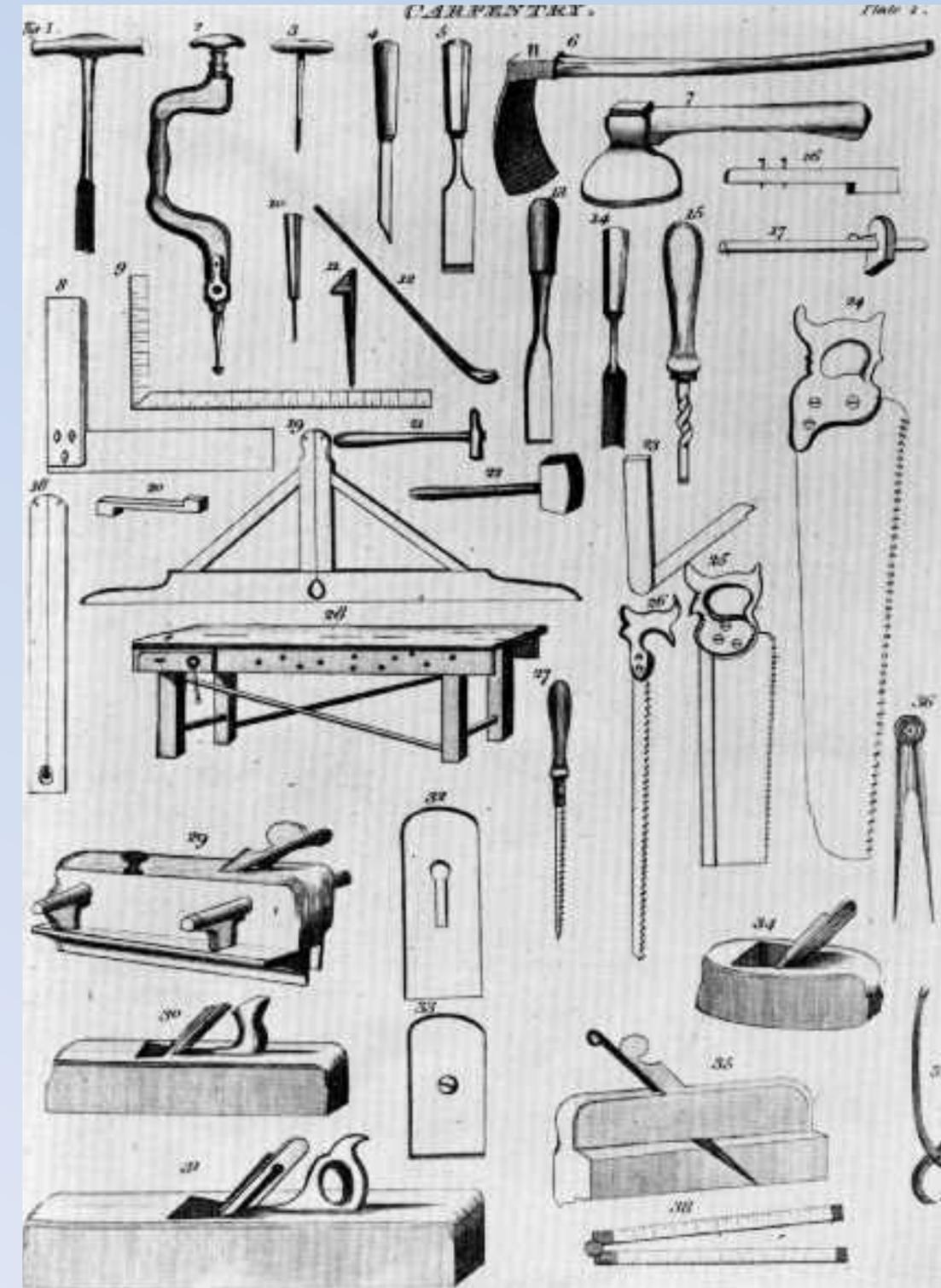
24+ Undergraduate and graduate courses

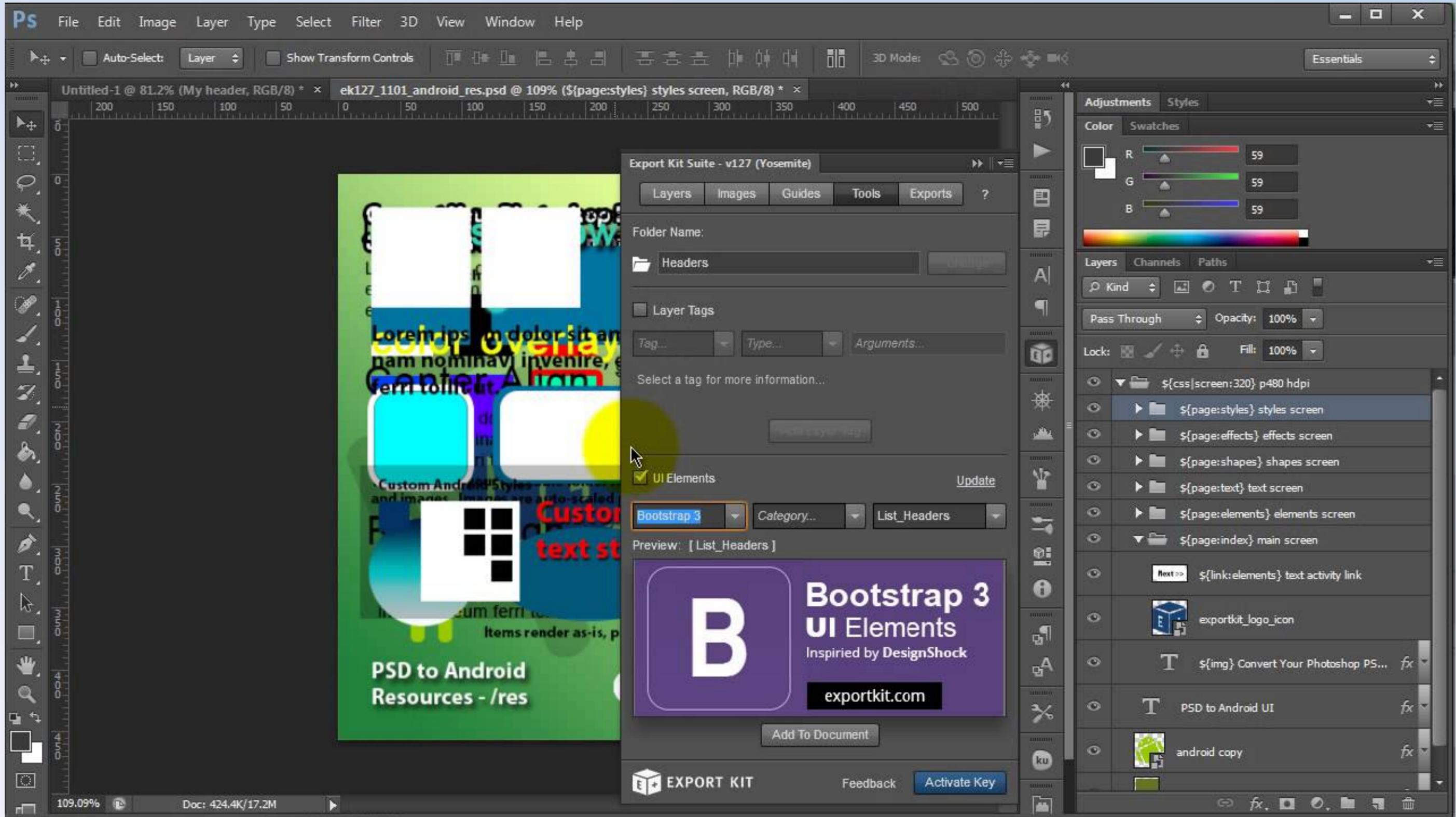
Carnegie Mellon University



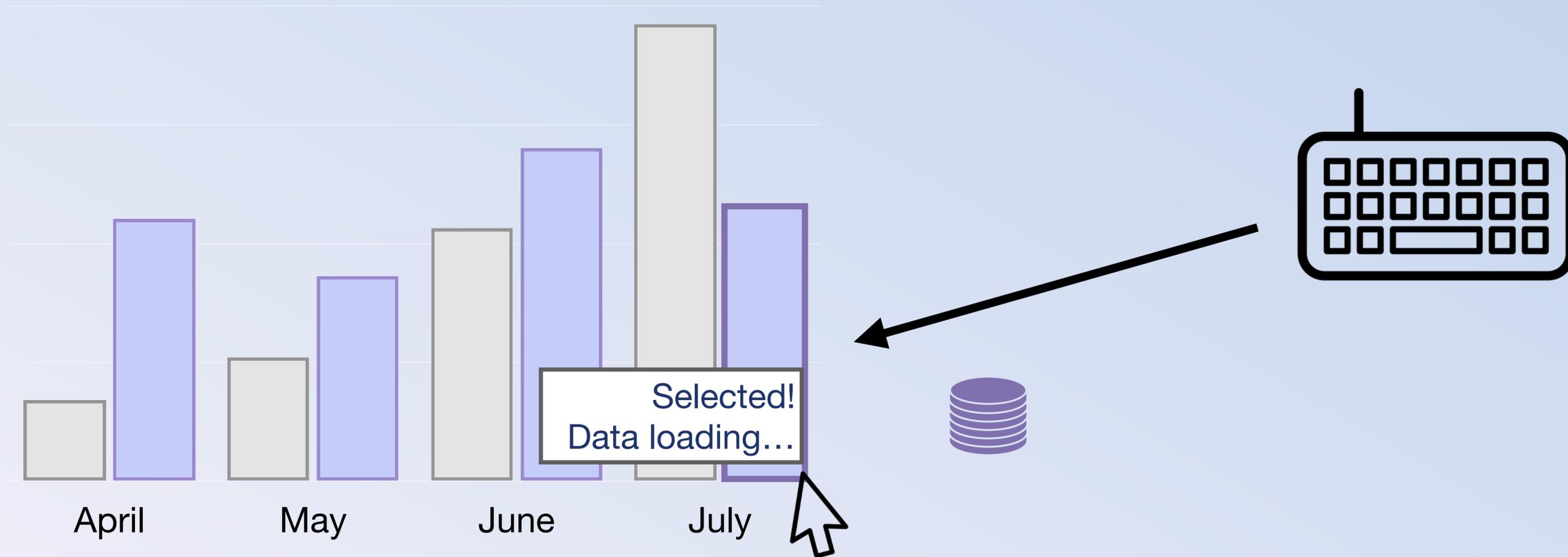
F. Elavsky, C. Bennett, and D. Moritz, "How accessible is my visualization? Evaluating visualization accessibility with *Chartability*," Computer Graphics Forum (EuroVis), 2022.

Tools for *complexity*:
Give people building
blocks for assembly





A keyboard should be able to do everything a mouse can



WAI. "Understanding success criterion 2.1.1: keyboard." *WCAG standard*, W3C, 2017.

Discrete and direct navigation face more barriers



A person in a wheelchair operating an old computer using a desk-mounted sip and puff device called the POSSUM.

Image credit: [Wikipedia](#), Public Domain, 1960. Photographer: Possum Ltd.

Rich navigation (a short history)

2015: “beyond the table” (highcharts)

The image shows a screenshot of the Highcharts Demos website. On the left is a navigation sidebar with the following categories:

- Highcharts Demos
- Search demo or tag
- core
 - Line charts
 - Area charts
 - Column and bar charts
 - Pie charts
 - Scatter and bubble charts
 - Combinations
 - Styled mode (CSS styling)
 - Accessibility
 - Audio charts
 - Dynamic charts
 - 3D charts
 - Gauges
 - Heat and tree maps
 - Trees and networks
 - More chart types

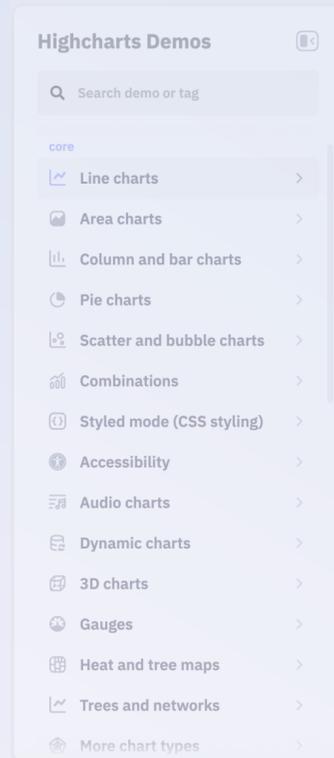
The main content area is titled "CORE Line charts" and displays a grid of 20 different chart demos, each with a title and a brief description:

- U.S. Solar Employment Growth (Line chart)
- Monthly Average Temperature (With data labels)
- Monthly Average Temperature (Spline with symbols)
- Atmosphere Temperature by Altitude (Spline with inverted axes)
- F1 2012 Top Ten Drivers (Line Race Chart)
- Growth of Internet Users Worldwide (logarithmic scale) (Logarithmic axis)
- United States of America's Inflation-related statistics (Line chart with custom entrance animation)
- Hourly forecast temperatures in Reykjavik, Iceland (Forecast)
- TSLA Stock price 2017 - Mar. (Stock data with annotations)
- Highcharts drawing 500000 points (Line chart with 500k points)
- USD to EUR exchange rate over time
- Wind speed during a day
- Snow depth at Vikjafjell, Norway
- Daily sessions at www.highcharts.com

Rich navigation (a short history)

2015 (highcharts)

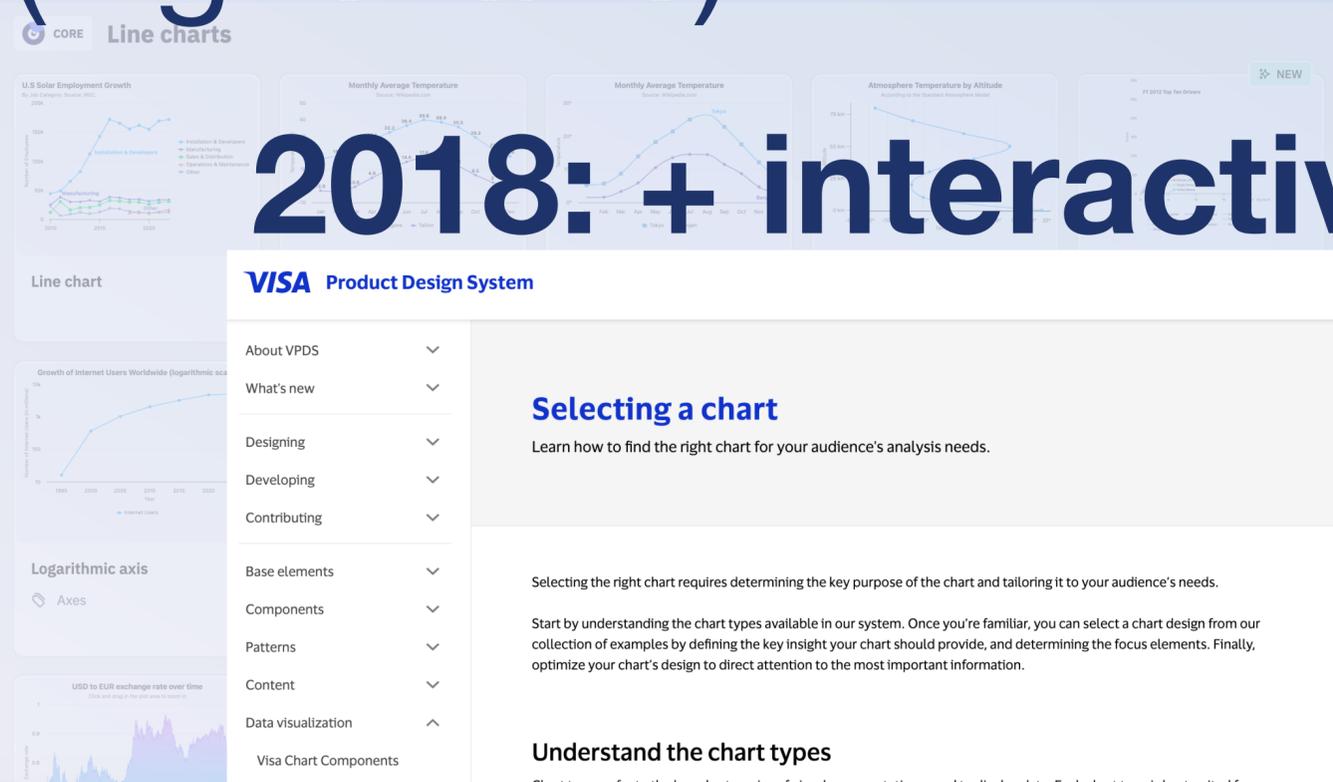
2018: + interactivity (visa charts)



Highcharts Demos

Search demo or tag

- core
- Line charts
- Area charts
- Column and bar charts
- Pie charts
- Scatter and bubble charts
- Combinations
- Styled mode (CSS styling)
- Accessibility
- Audio charts
- Dynamic charts
- 3D charts
- Gauges
- Heat and tree maps
- Trees and networks
- More chart types



CORE Line charts

U.S. Solar Employment Growth

Monthly Average Temperature

Monthly Average Temperature

Atmosphere Temperature by Altitude

Line chart

Growth of Internet Users Worldwide (logarithmic scale)

Logarithmic axis

US\$ to EUR exchange rate over time

VISA Product Design System

- About VPDS
- What's new
- Designing
- Developing
- Contributing
- Base elements
- Components
- Patterns
- Content
- Data visualization
- Visa Chart Components
- Development setup
- Design visualization guidelines
- Overview
- Data visualization principles
- Selecting a chart

Selecting a chart

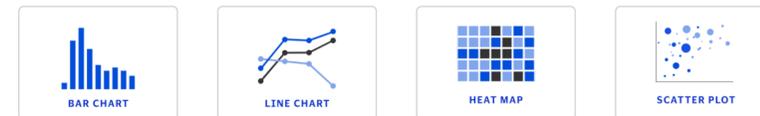
Learn how to find the right chart for your audience's analysis needs.

Selecting the right chart requires determining the key purpose of the chart and tailoring it to your audience's needs.

Start by understanding the chart types available in our system. Once you're familiar, you can select a chart design from our collection of examples by defining the key insight your chart should provide, and determining the focus elements. Finally, optimize your chart's design to direct attention to the most important information.

Understand the chart types

Chart types refer to the broad categories of visual representations used to display data. Each chart type is best-suited for particular kinds of data analysis or insights. Charts help users understand and interpret data by leveraging simplified visual representations that highlight patterns and relationships.



ON THIS PAGE

Understand the chart types

Selecting a chart

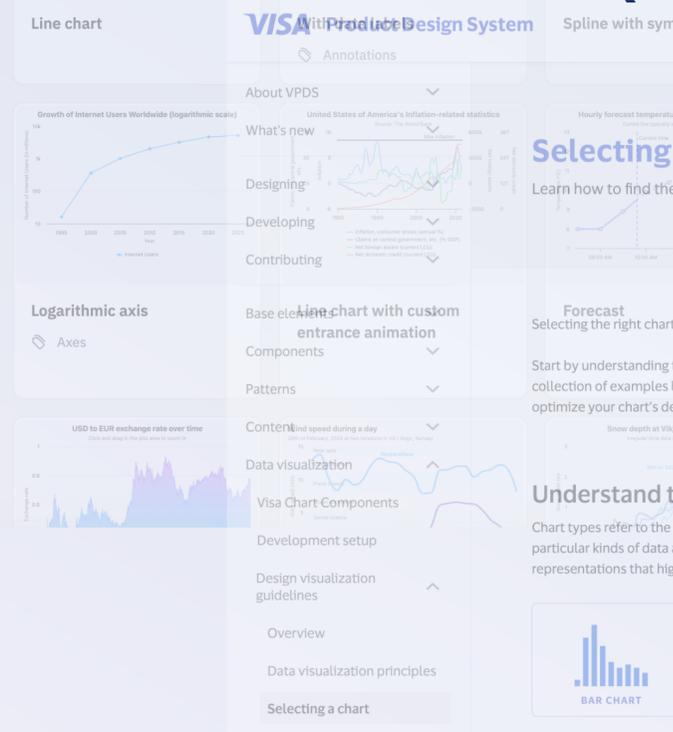
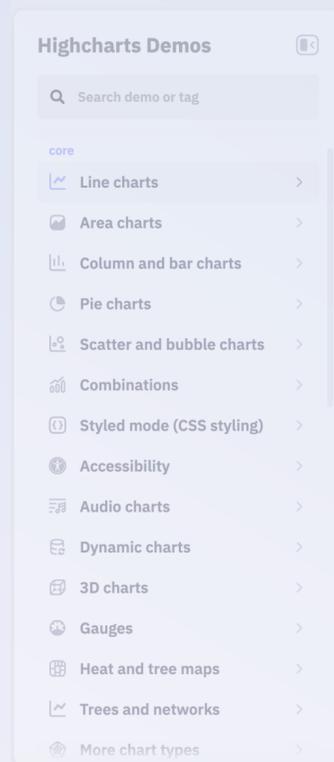
Step 1: Choose a key insight category

Step 2: Determine the focus

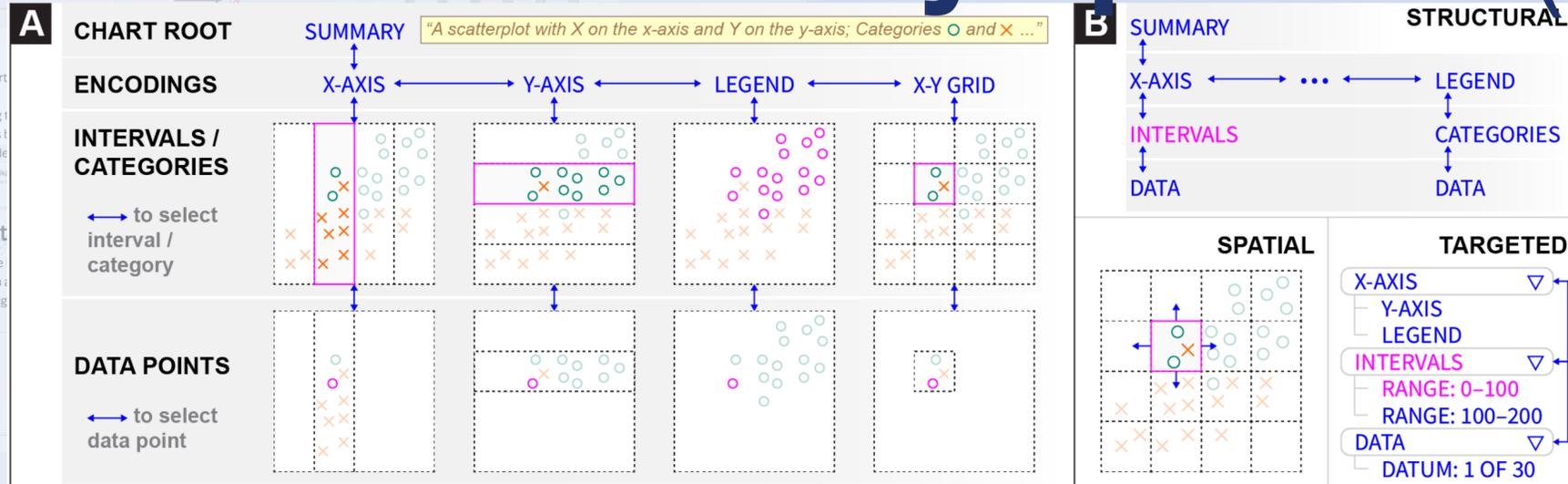
Step 3: Refine the chart

Rich navigation (a short history)

2015 (highcharts)

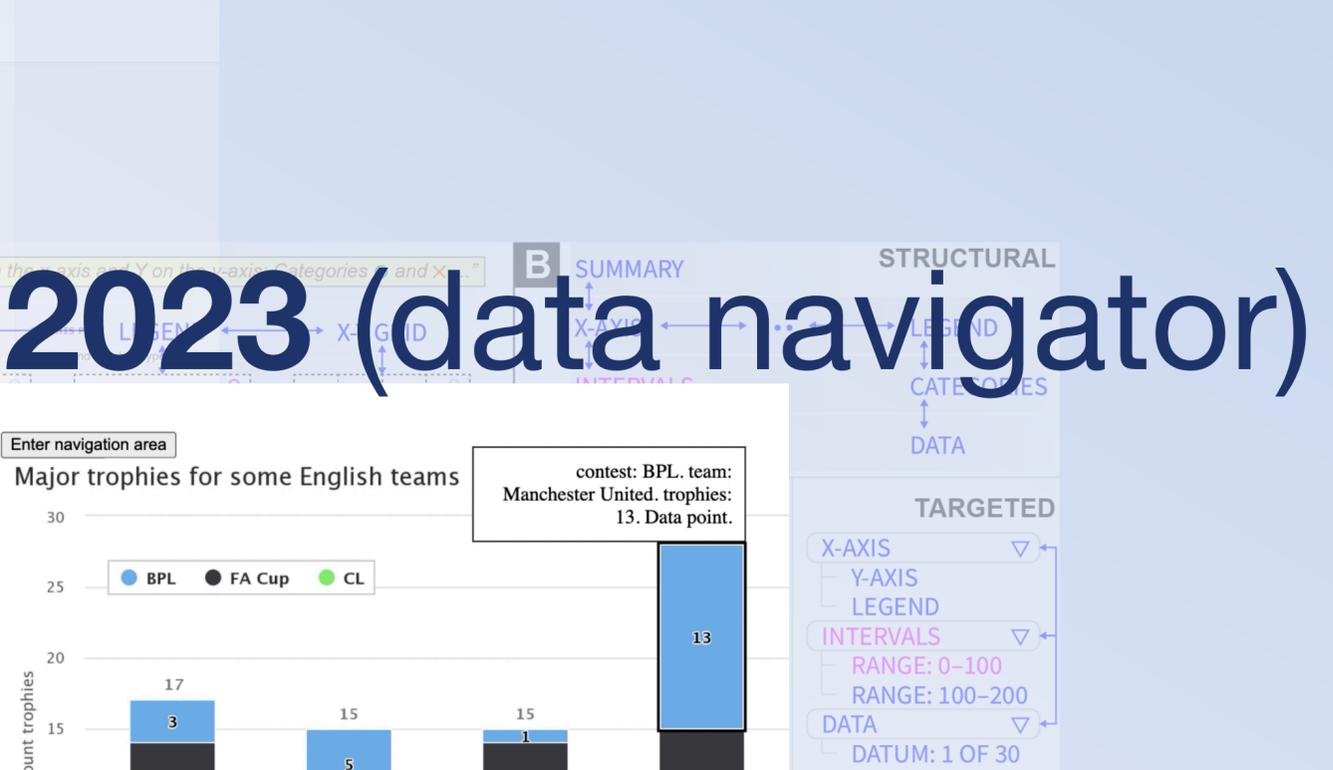
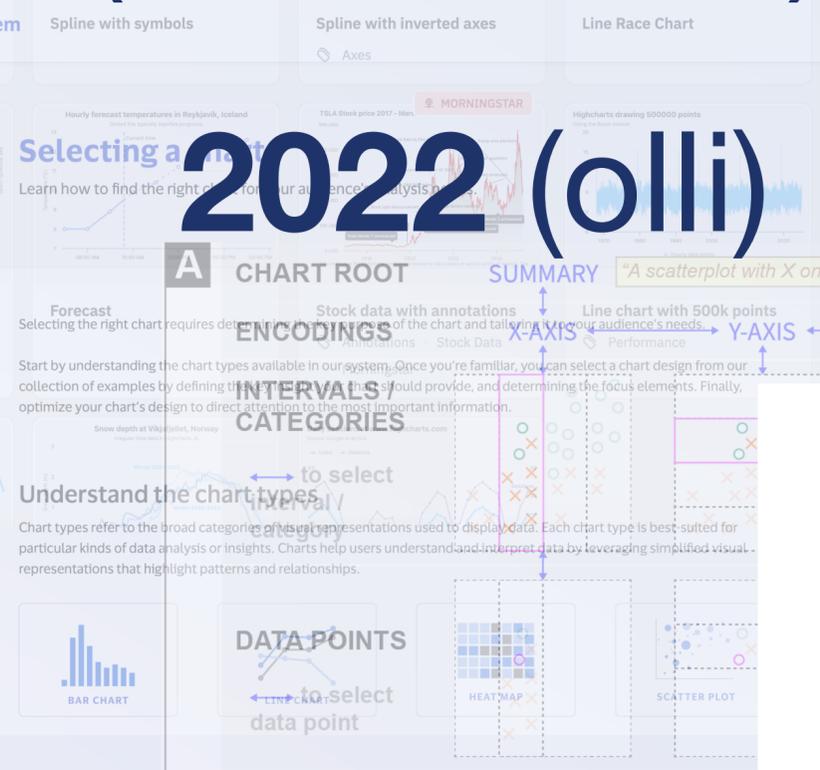
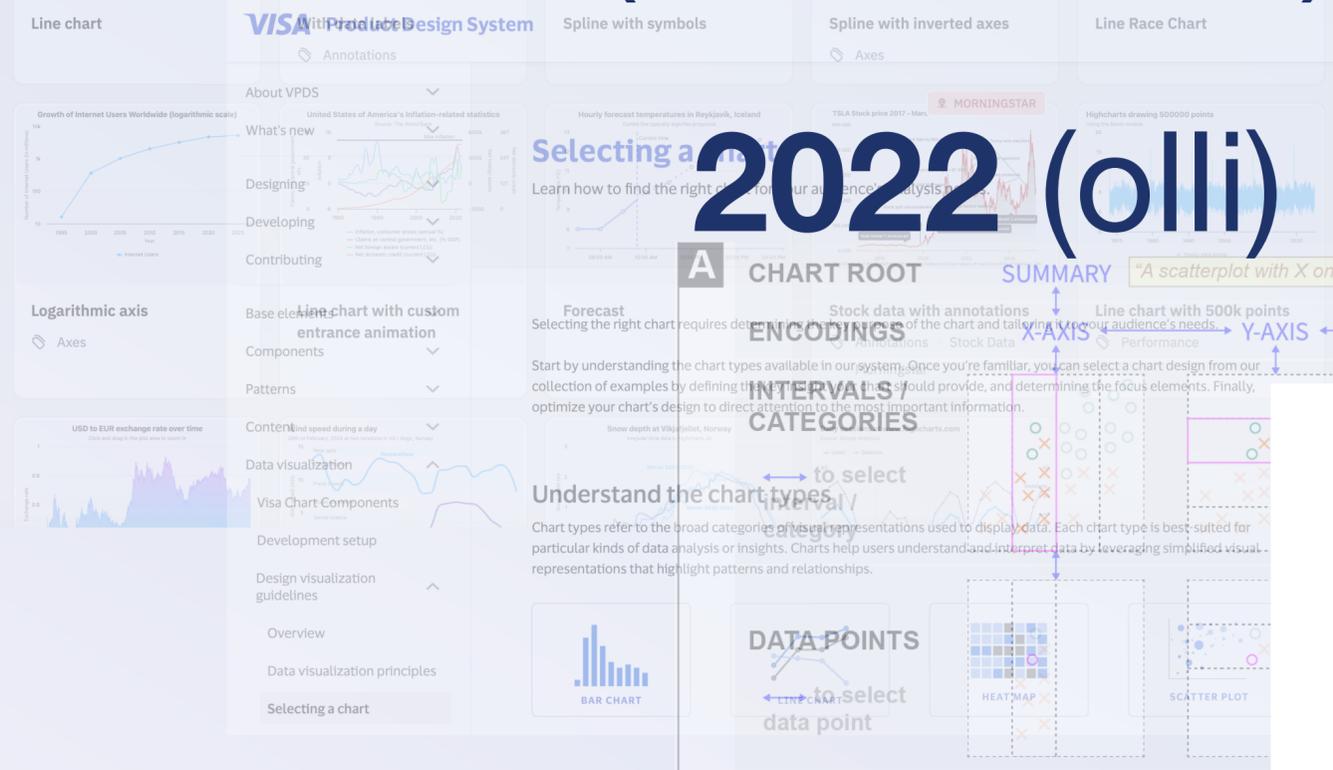
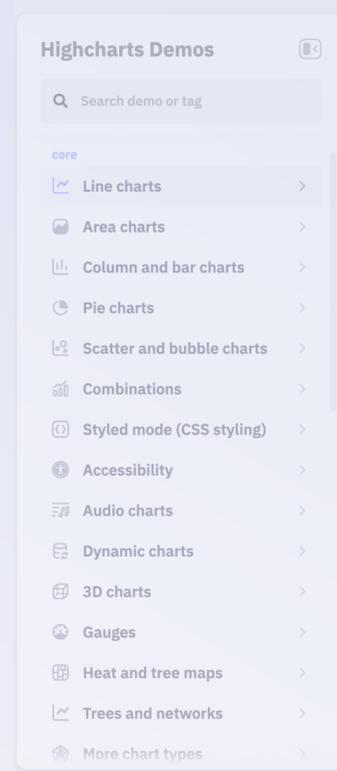


2022: not library specific (olli)



Rich navigation (a short history)

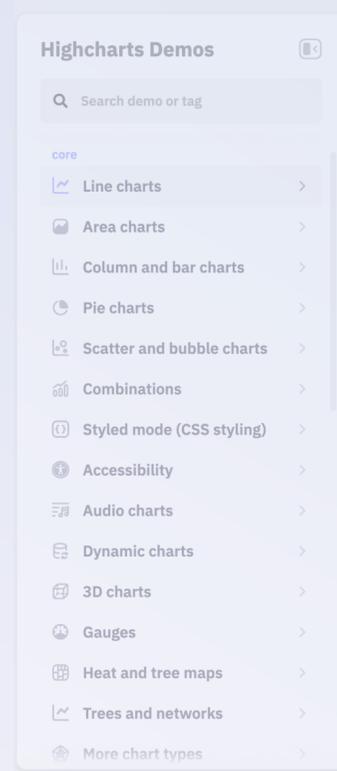
2015 (highcharts)



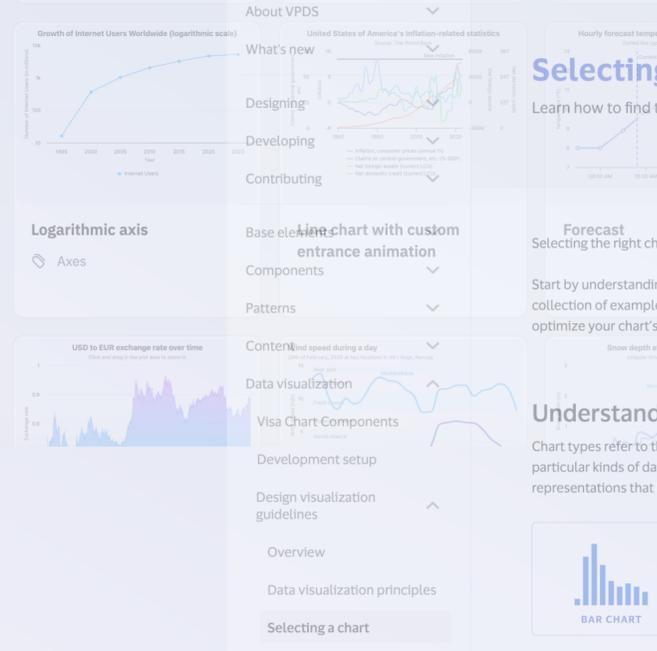
F. Elavsky, L. Nadolskis, and D. Moritz, “Data Navigator: An Accessibility-Centered Data Navigation Toolkit,” *IEEE Transactions on Visualization and Computer Graphics*, 2023.

Rich navigation (a short history)

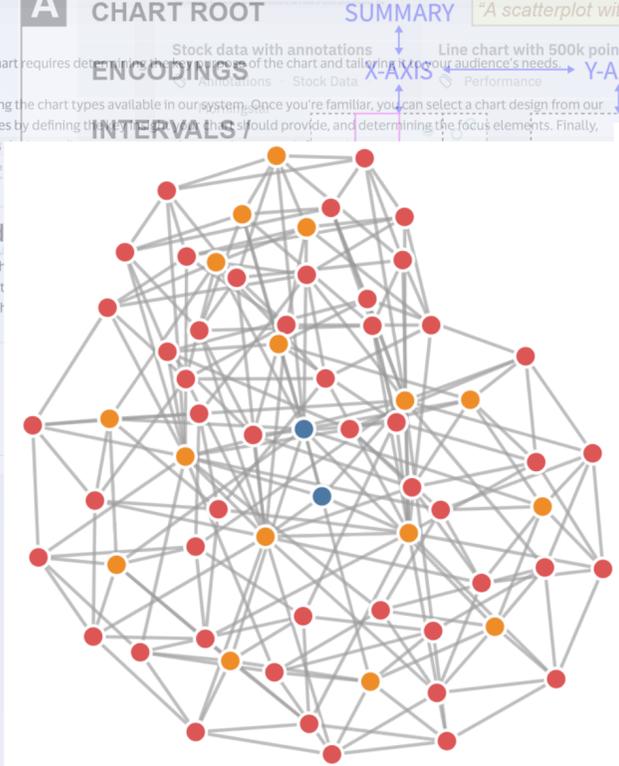
2015 (highcharts)



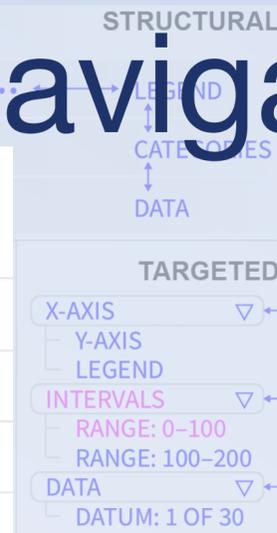
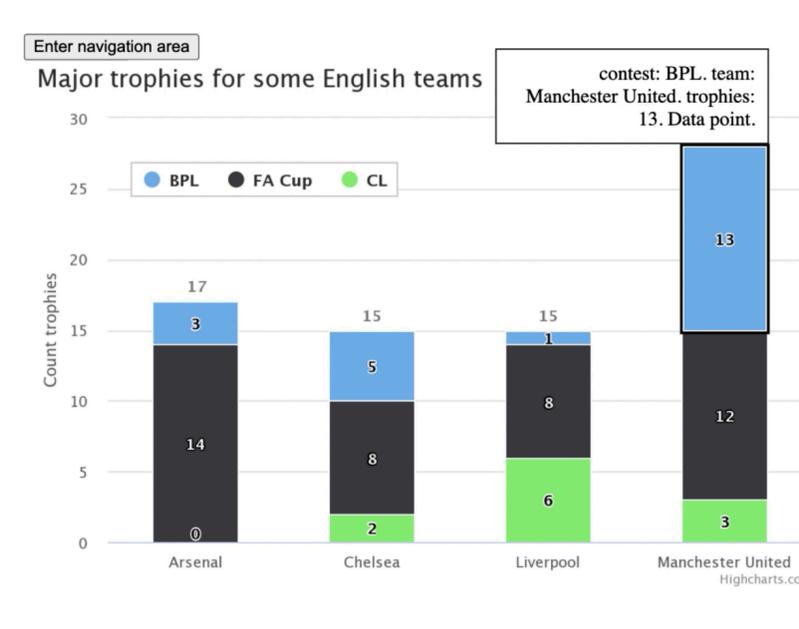
2018 (visa charts)



2022 (olli)



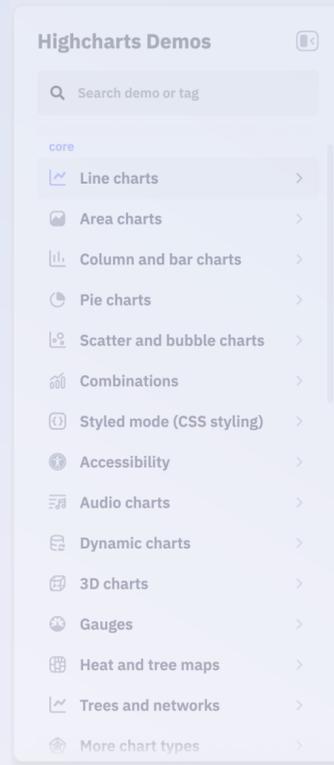
2023 (data navigator)



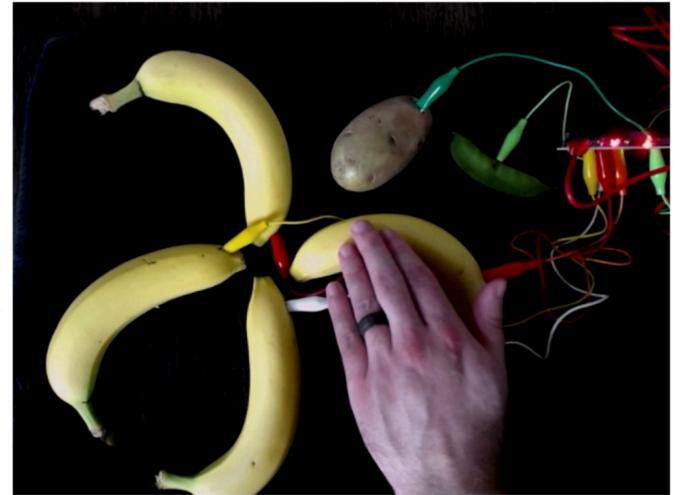
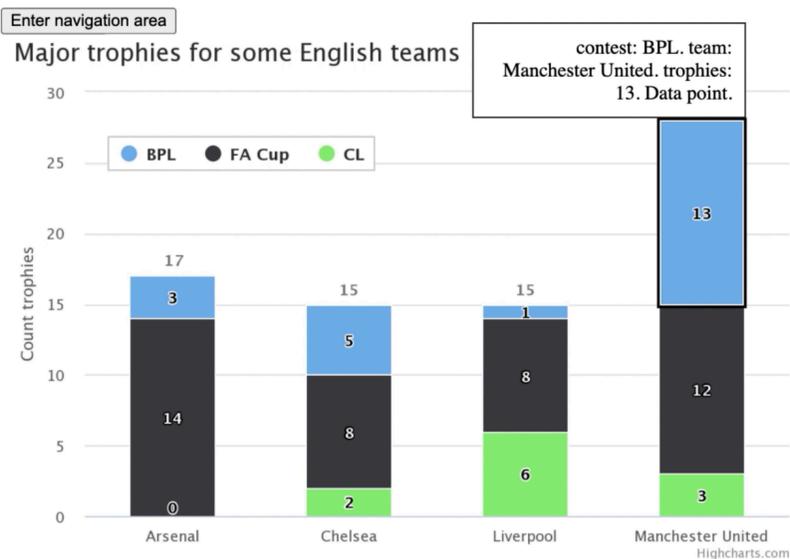
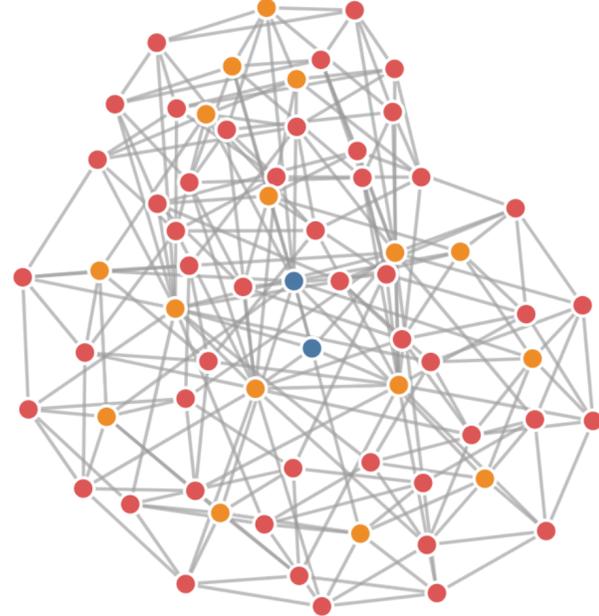
F. Elavsky, L. Nadolskis, and D. Moritz, “Data Navigator: An Accessibility-Centered Data Navigation Toolkit,” *IEEE Transactions on Visualization and Computer Graphics*, 2023.

Rich navigation (a short history)

2015 (highcharts)

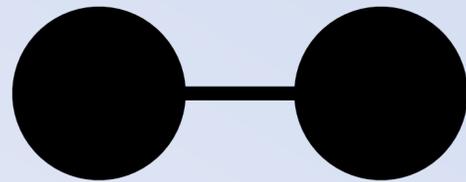


2023 (data navigator)



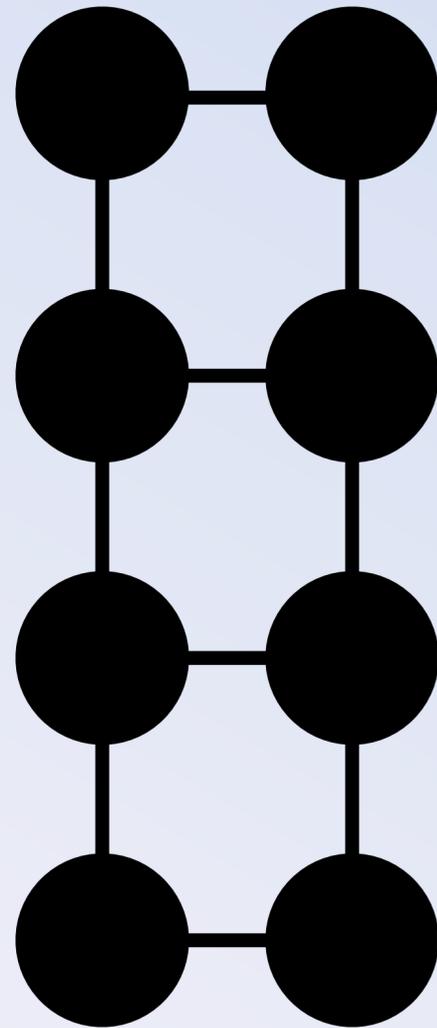
F. Elavsky, L. Nadolskis, and D. Moritz, "Data Navigator: An Accessibility-Centered Data Navigation Toolkit," *IEEE Transactions on Visualization and Computer Graphics*, 2023.

Structure is a *graph*: nodes and edges



Graphs can create nearly all *other* structures

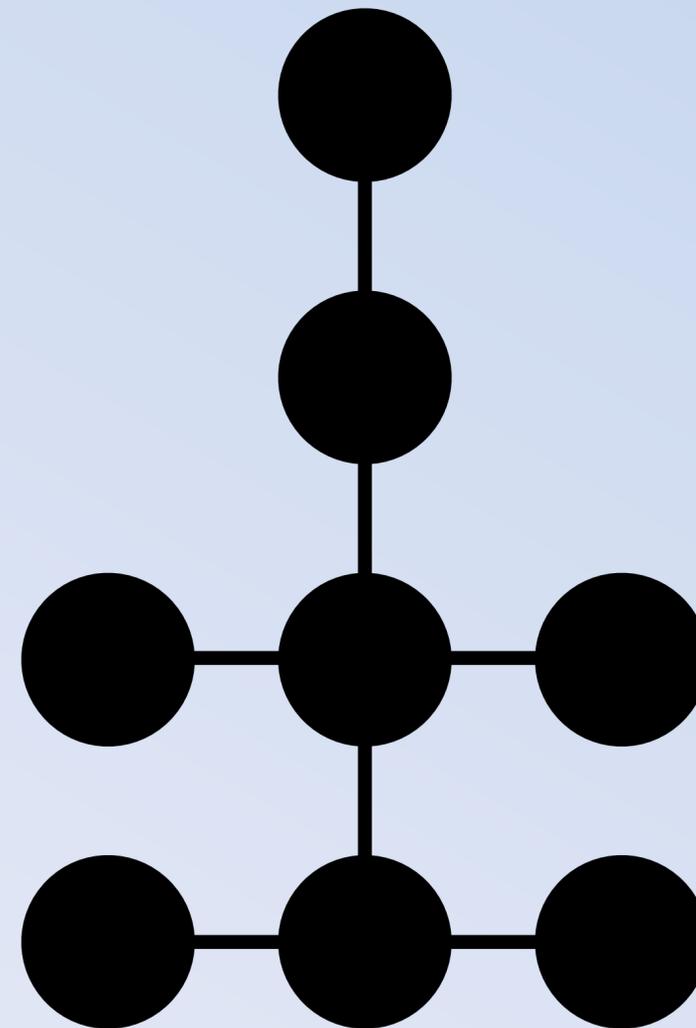
Tables



Lists

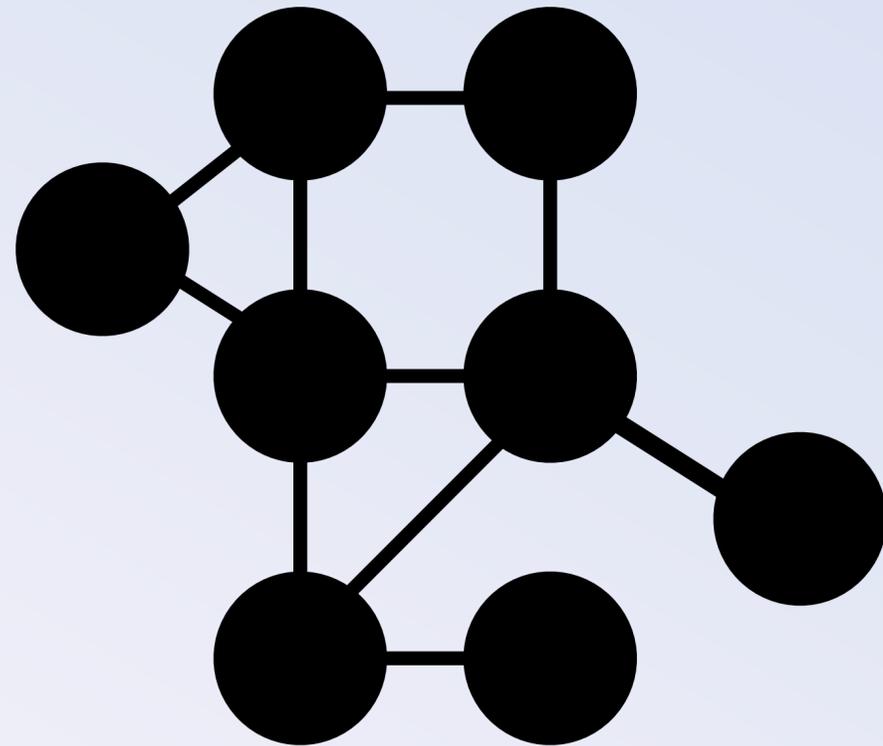


Hierarchies

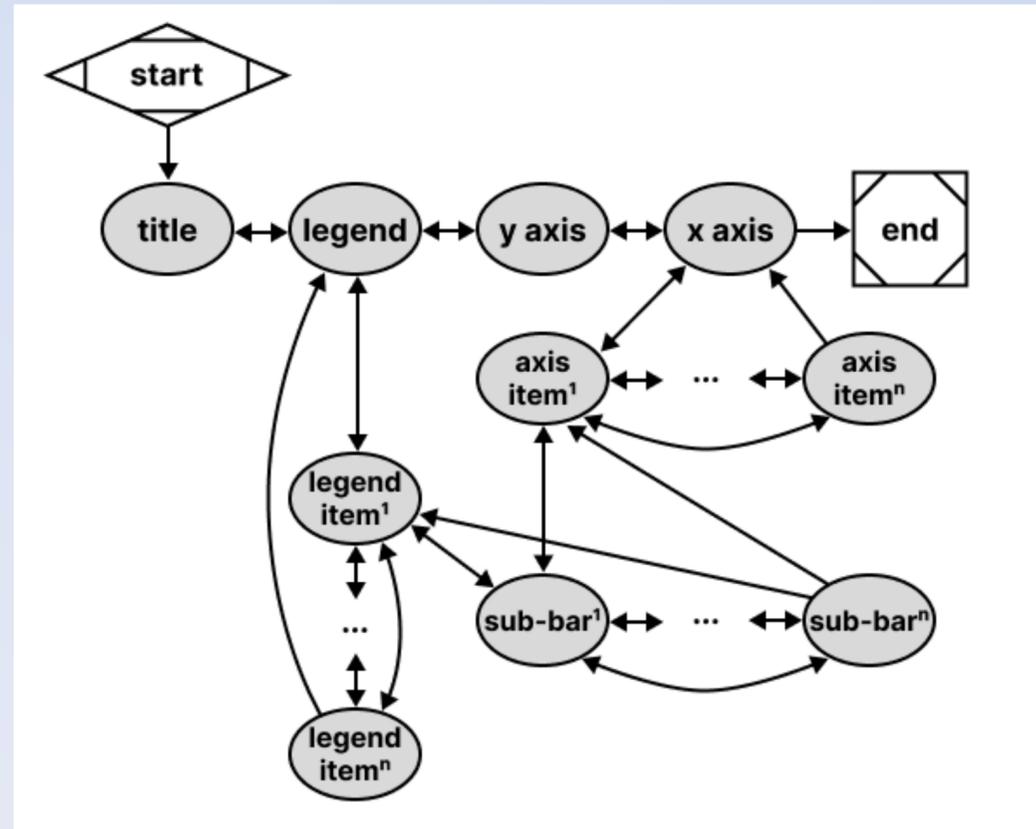


Nodes can become virtually anything

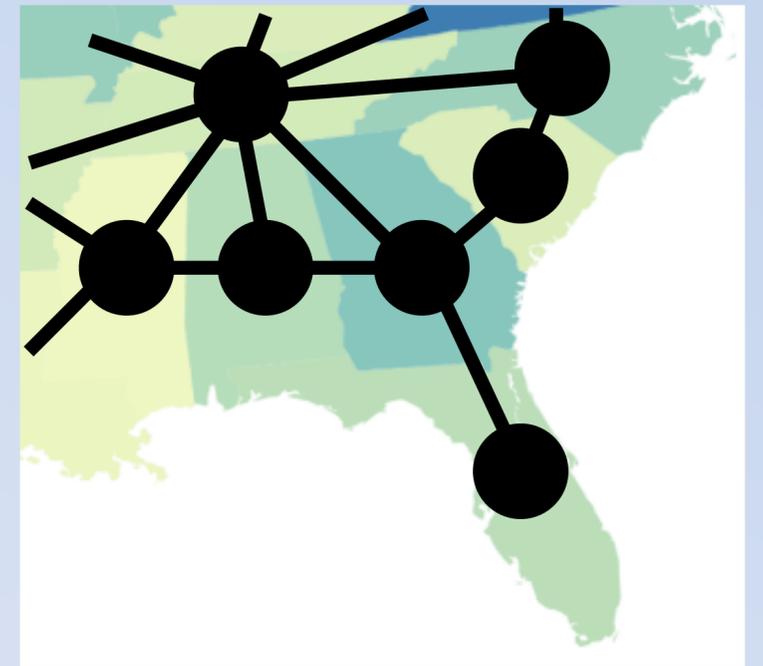
Network graphs



Diagrams



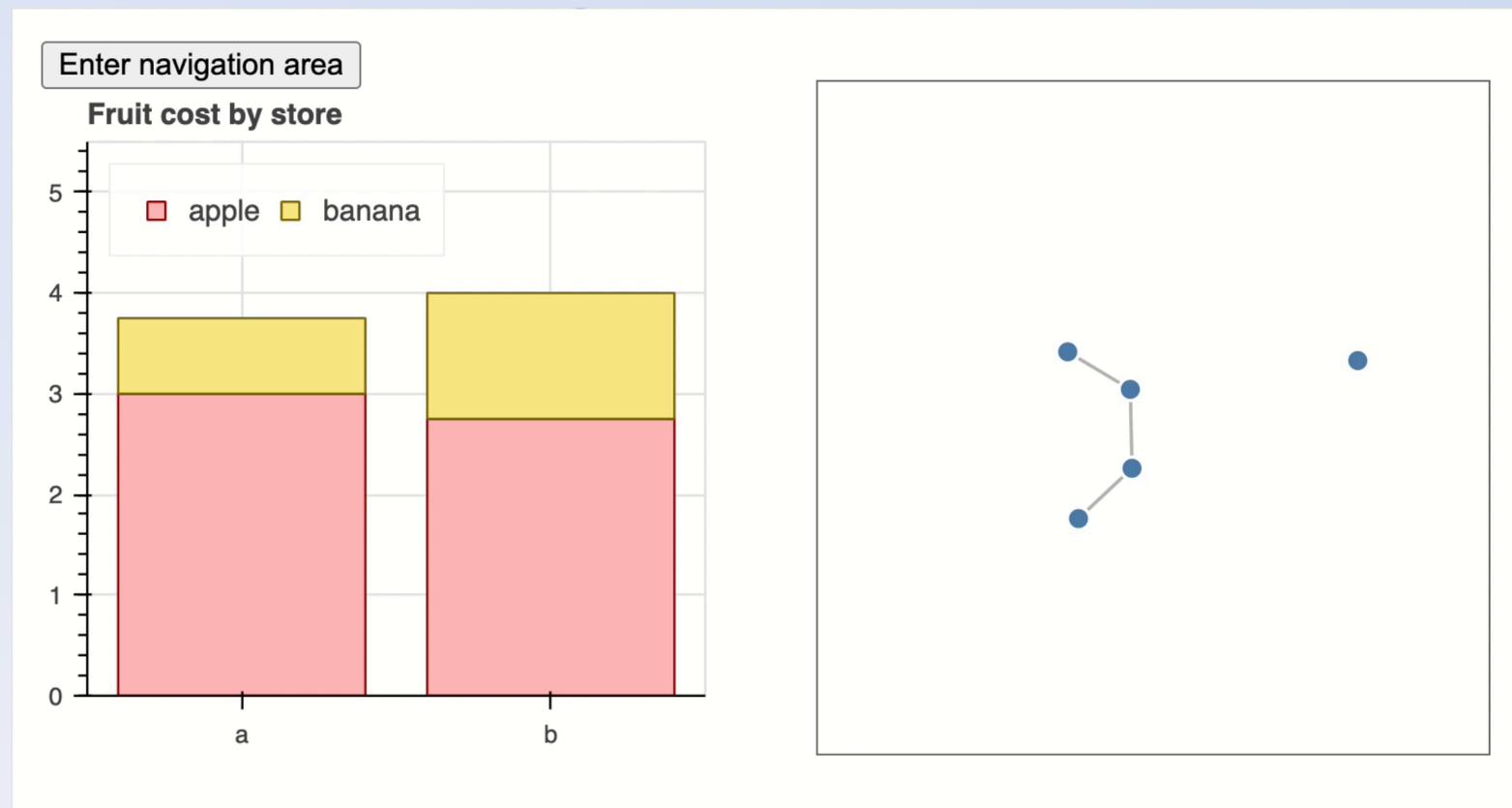
Maps



Data Navigator: Empowering practitioners

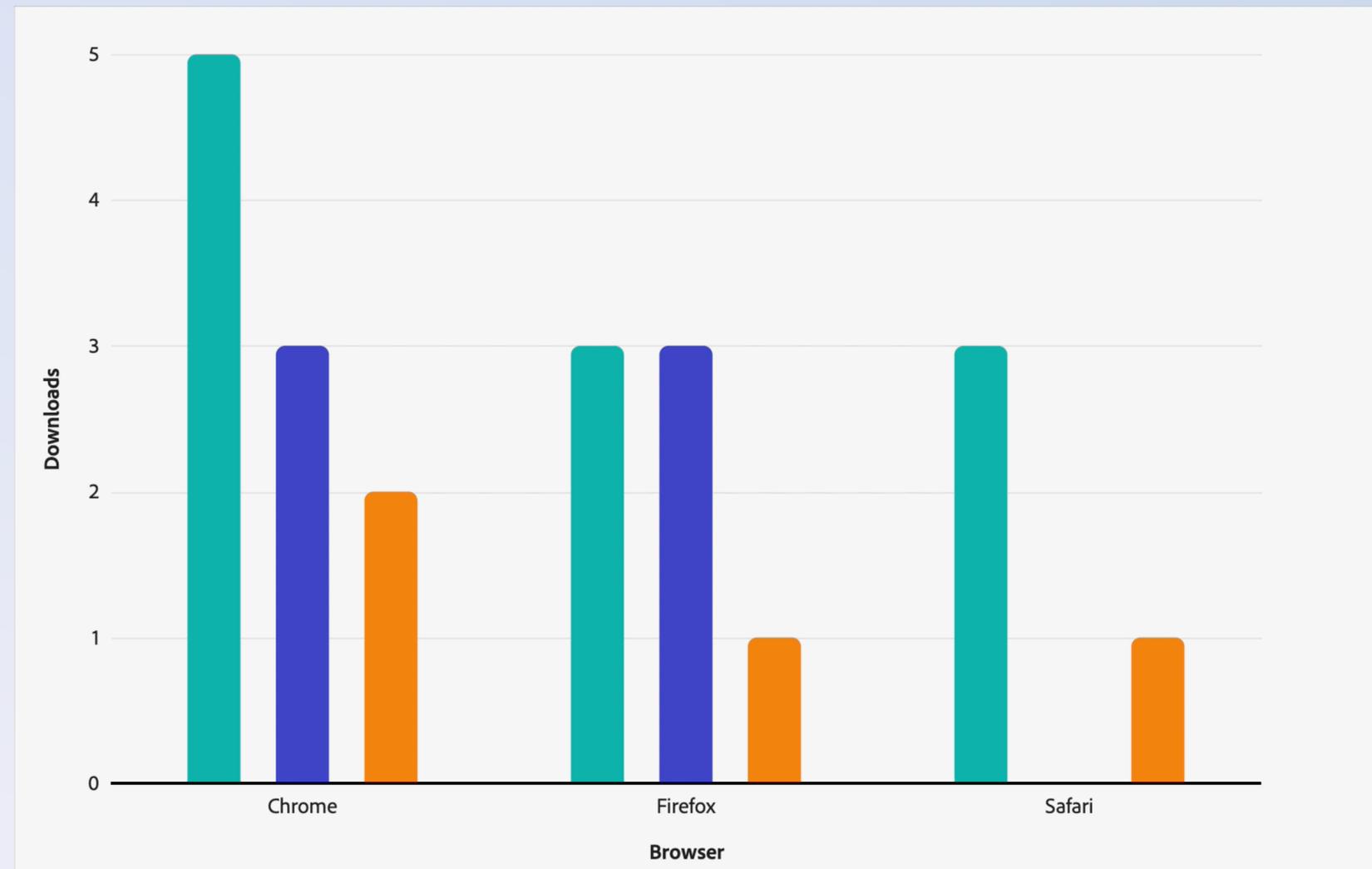
Bokeh, a python visualization library

(Acquired \$200k USD CZI EOSS Grant with Quansight+Anaconda)



Data Navigator: Empowering practitioners

React Spectrum Charts, Adobe's visualization design system
(Acquired \$40k prototype funding + \$200k research gift)



Navigation + Animation

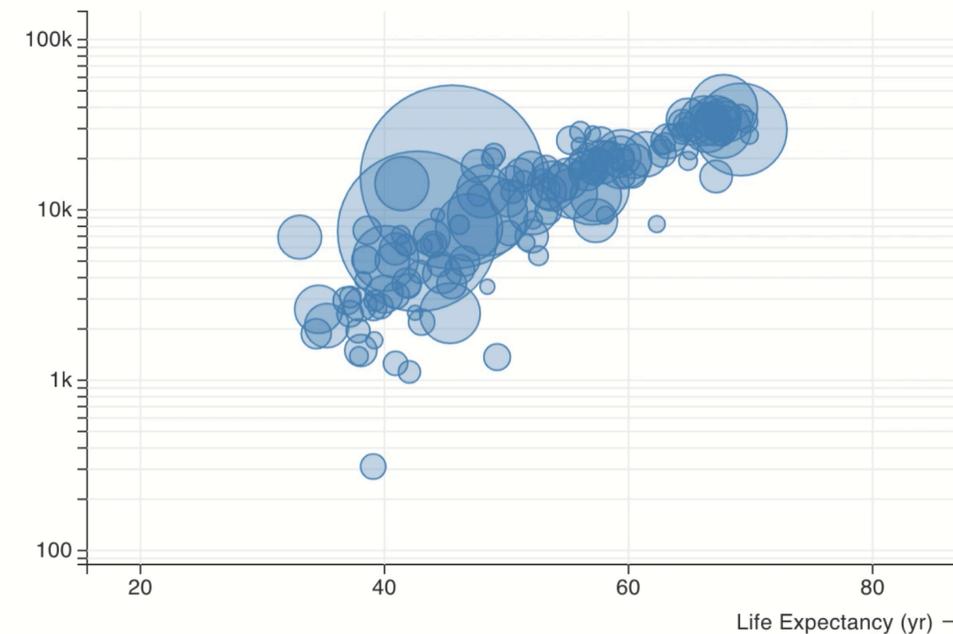


Example: Accessible Gapminder Chart

Below is a responsive, screen-reader-navigable version of the chart shown on the [homepage](#). Press **Navigate** to enter keyboard navigation. Or, change your “prefers reduced motion” system setting to see fade animations instead of motion.

Navigate

↑ GDP Per Capita



Year: 1992



Play/Pause

X axis:

Life Expectancy ▾

Y axis:

GDP Per Capita ▾

Radius:

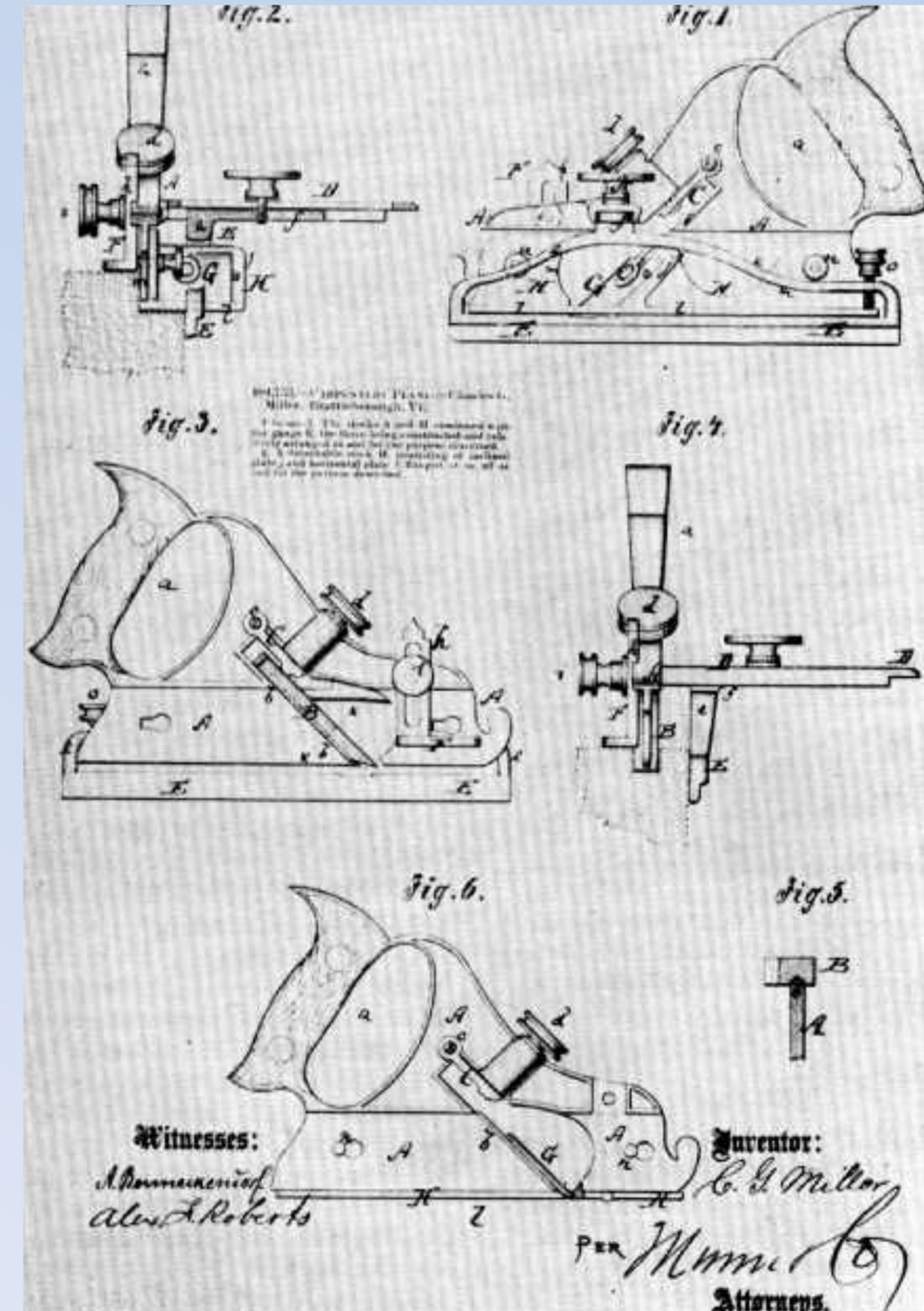
Population ▾

Reset Zoom

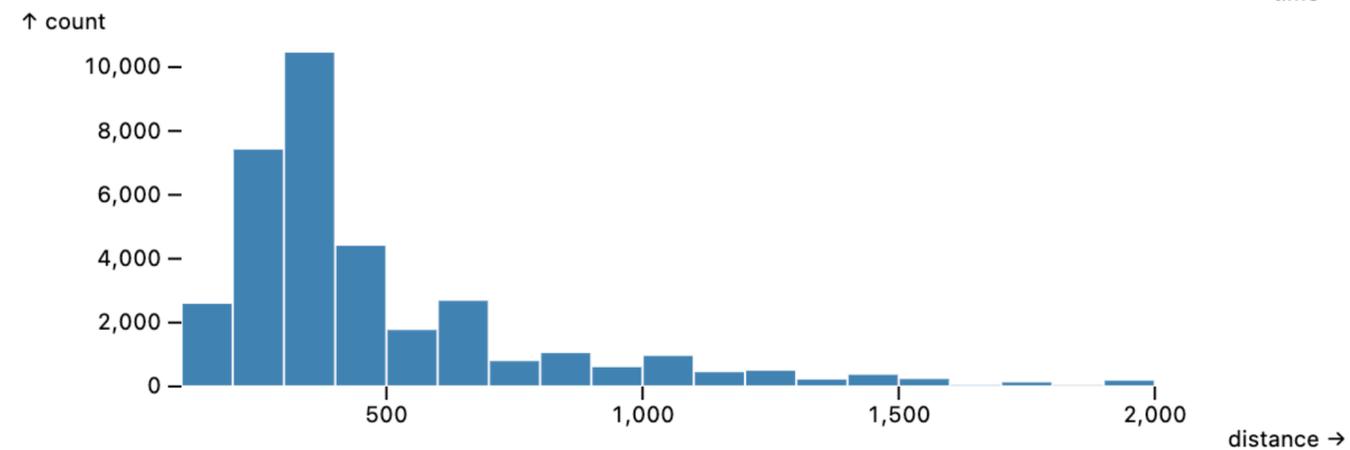
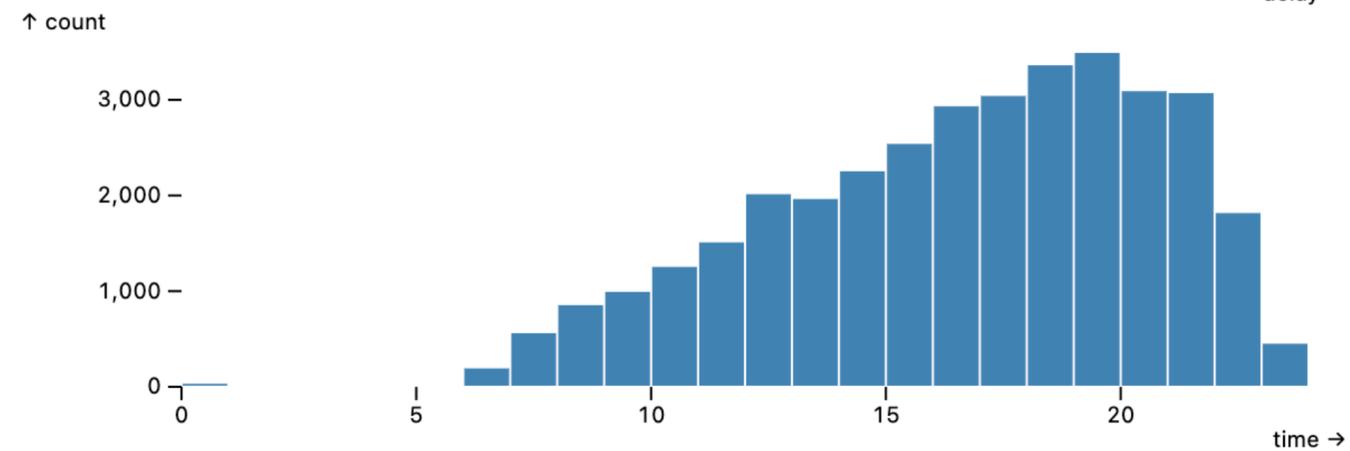
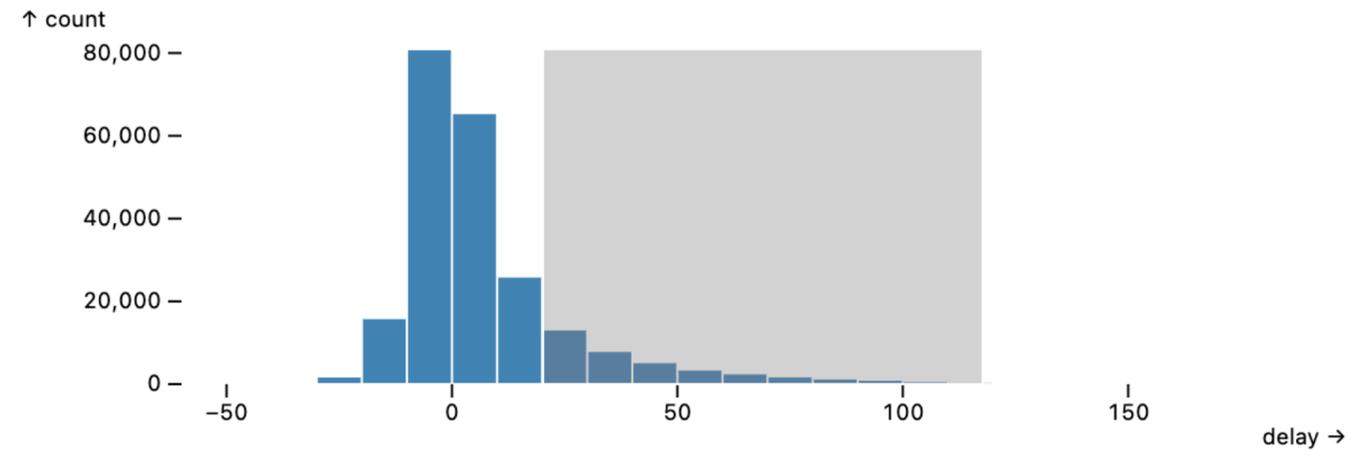
Source: Free Data from World Bank via gapminder.org, CC-BY license

V. Sivaraman, **F. Elavsky**, D. Moritz, and A. Perer. “Counterpoint: Orchestrating large- scale custom animated visualizations.” *IEEE Visualization and Visual Analytics*, 2024.

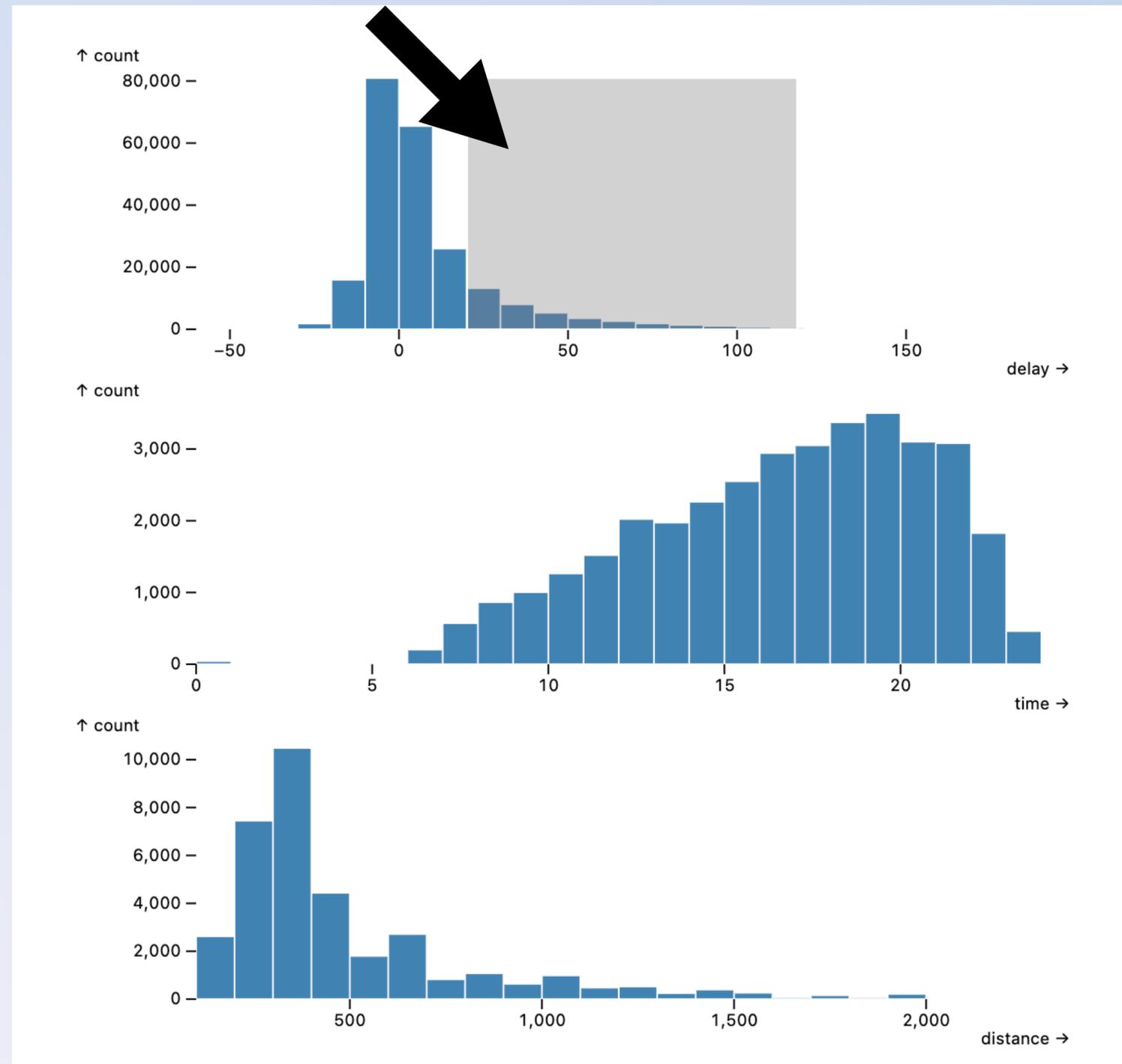
Tools for *possibility*: Enable people with new materials



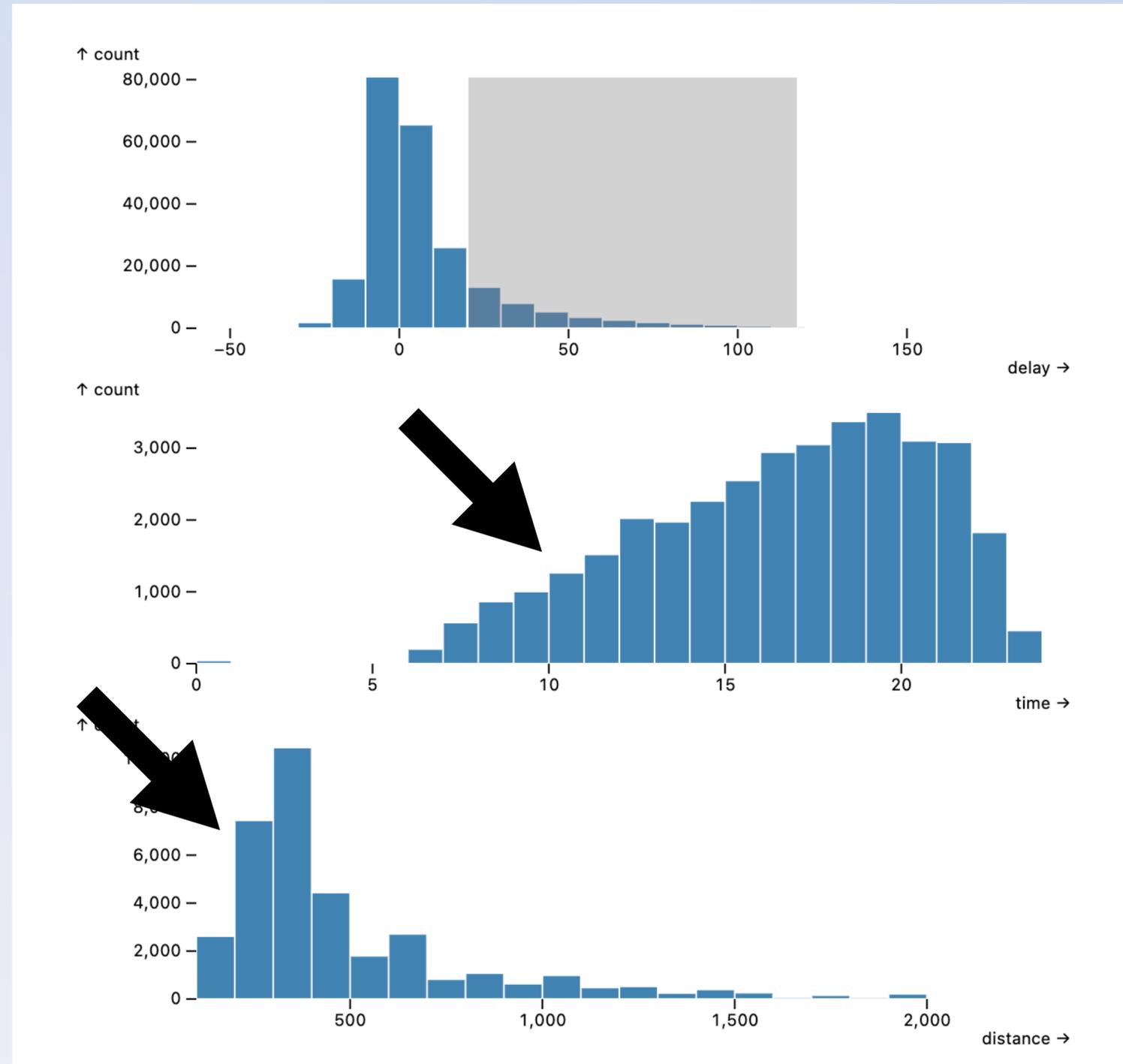
So what about cross-filtering?



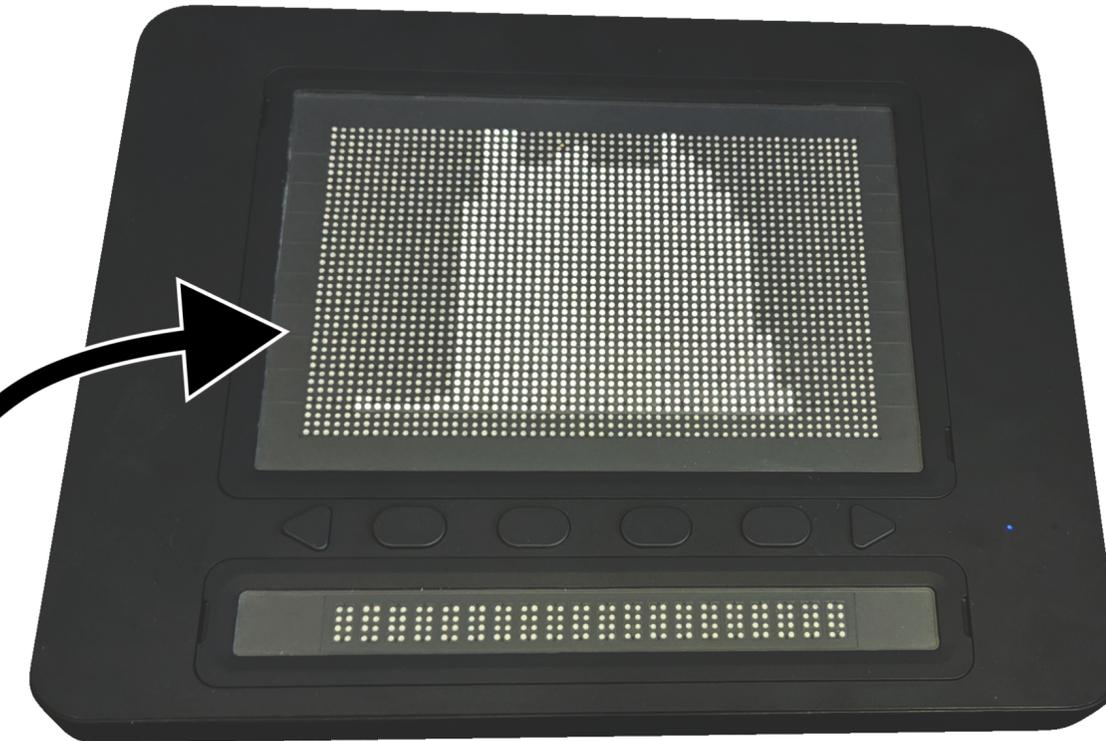
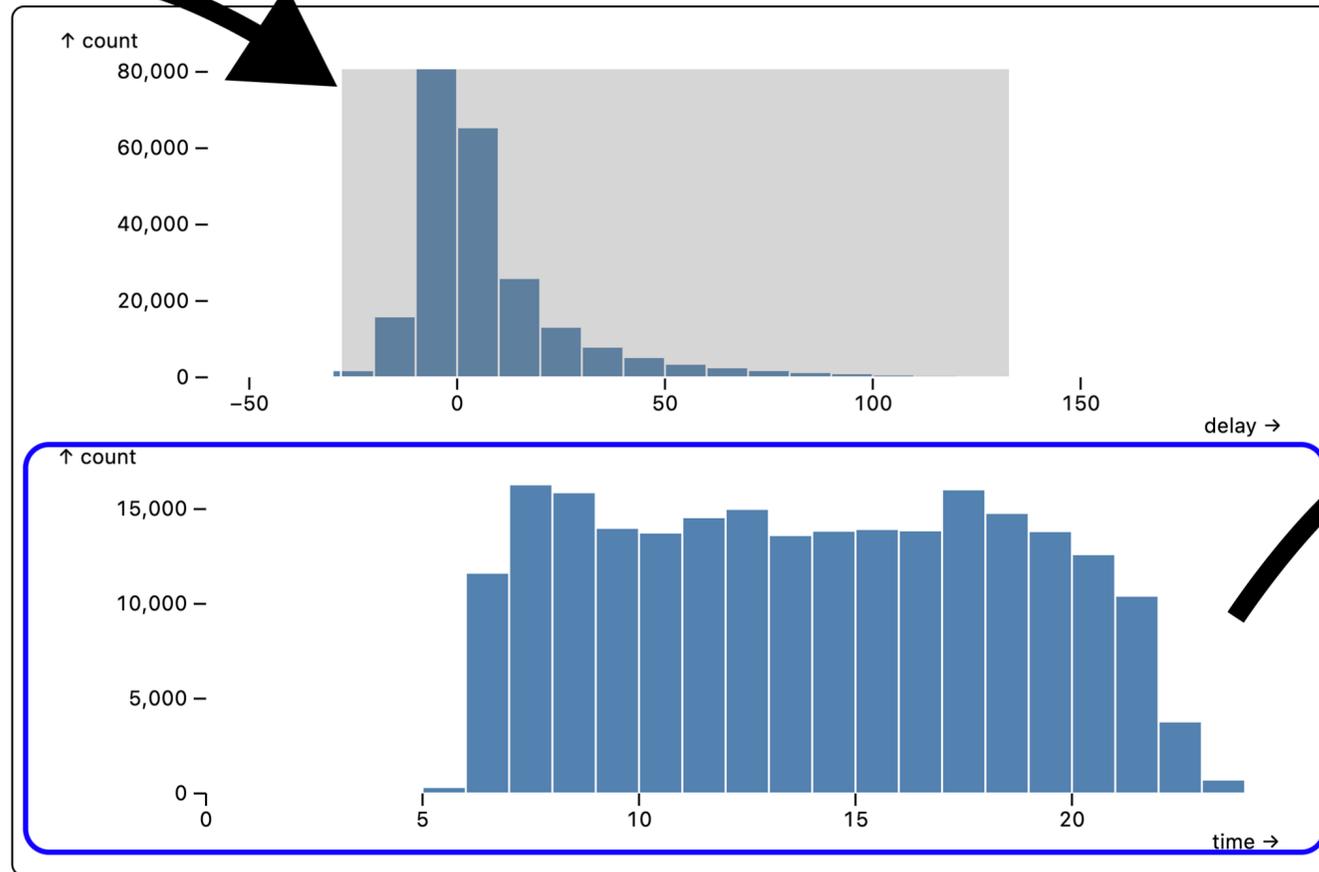
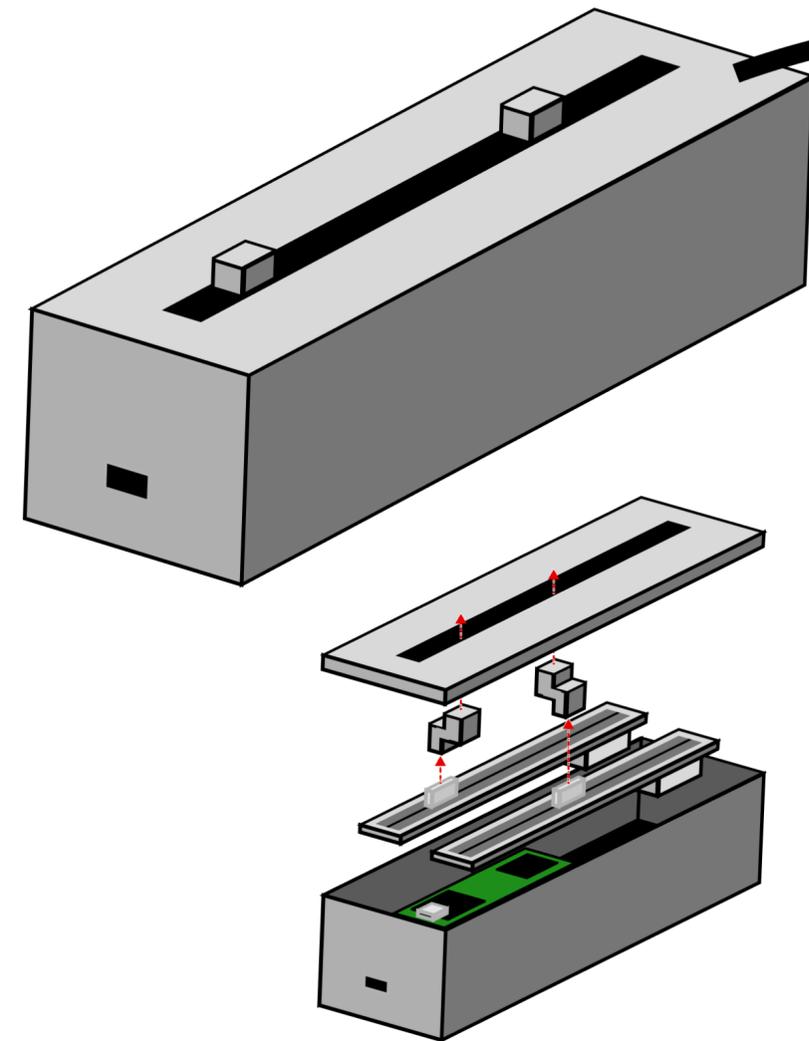
Interaction in one space...



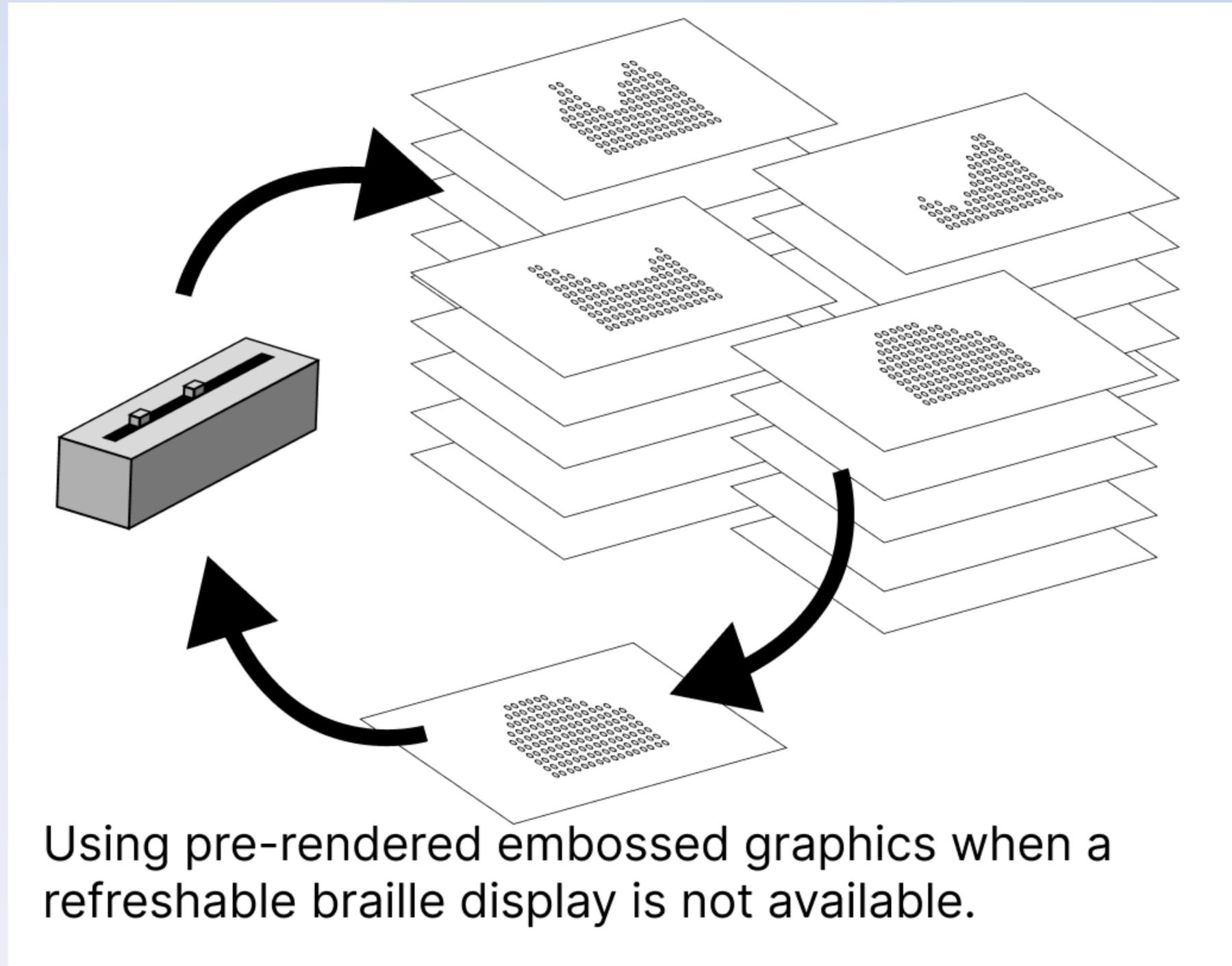
Produces simultaneous, coordinated change in another.



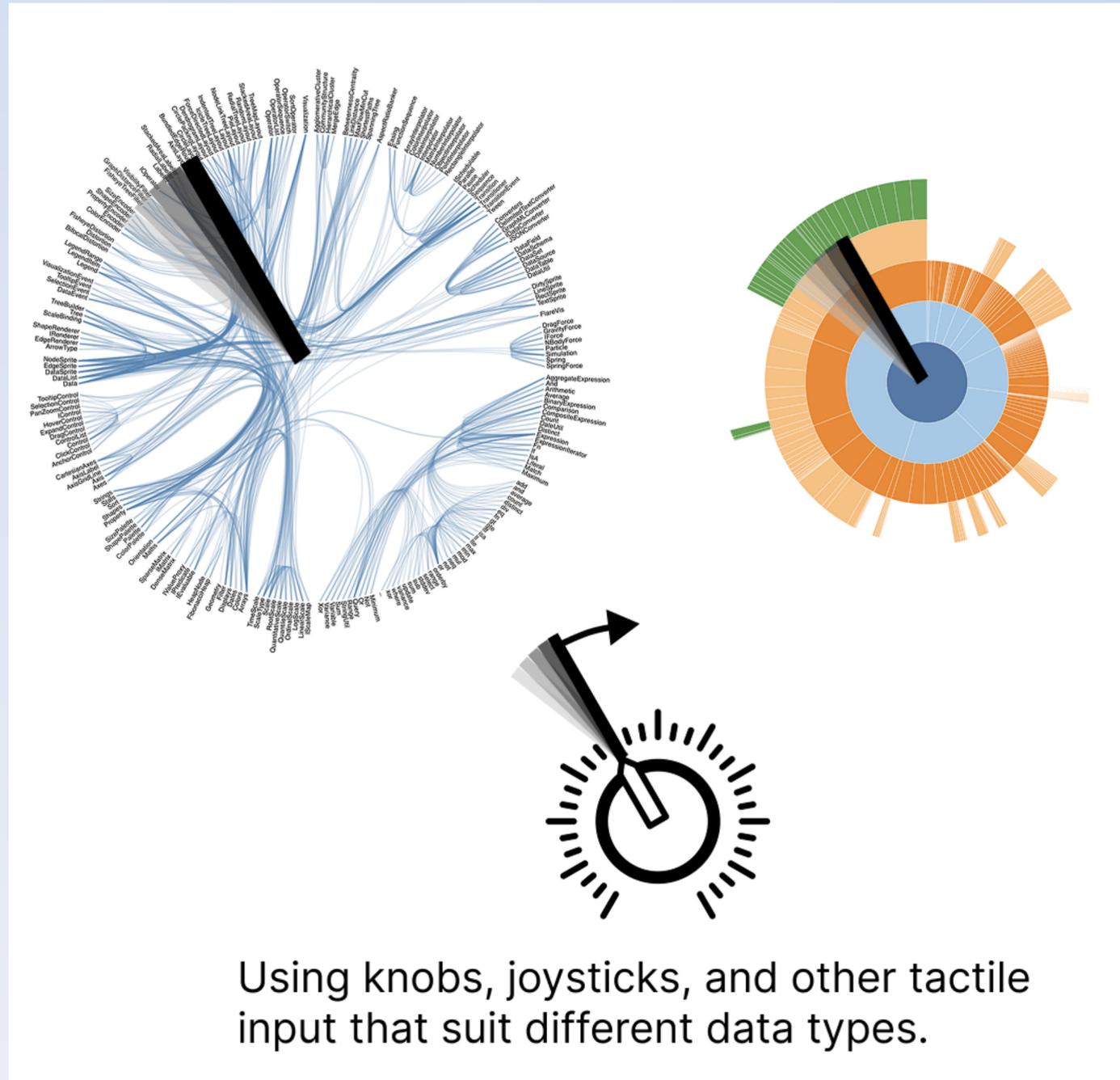
Cross-feelting! A tactile, dual-task paradigm.



How might we use *cross-feel* for new experiences?



How might we use *cross-feelting* for new experiences?



Data, Accessibility, and Tools

Tools for *explanation*

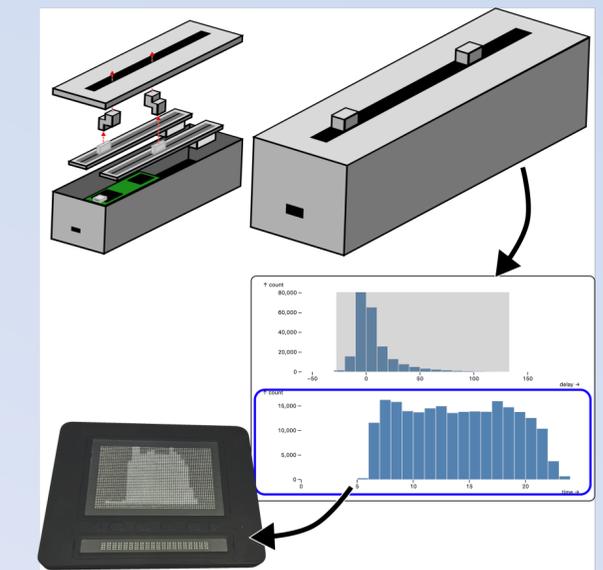
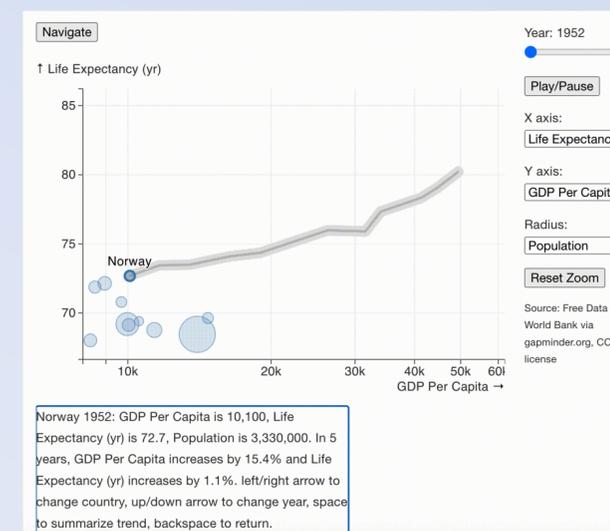
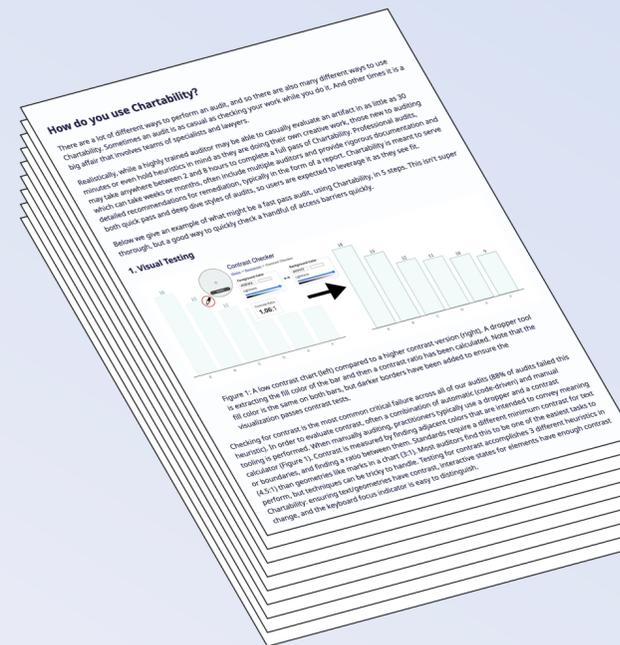
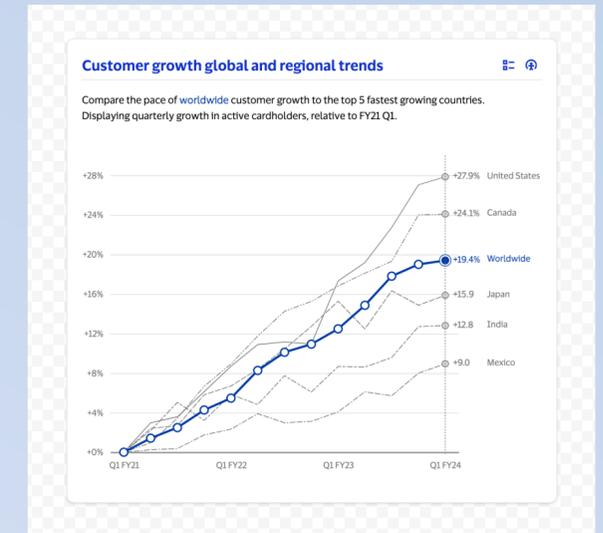
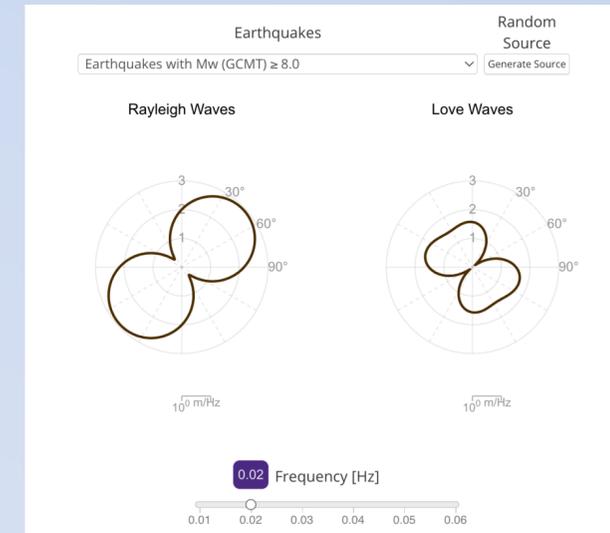
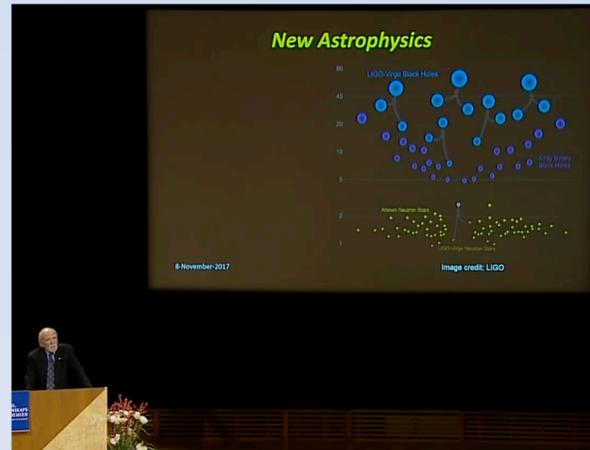
Tools for *exploration*

Tools for *scale*

Tools for *thinking*

Tools for *complexity*

Tools for *possibility*



Data, Accessibility, and Tools



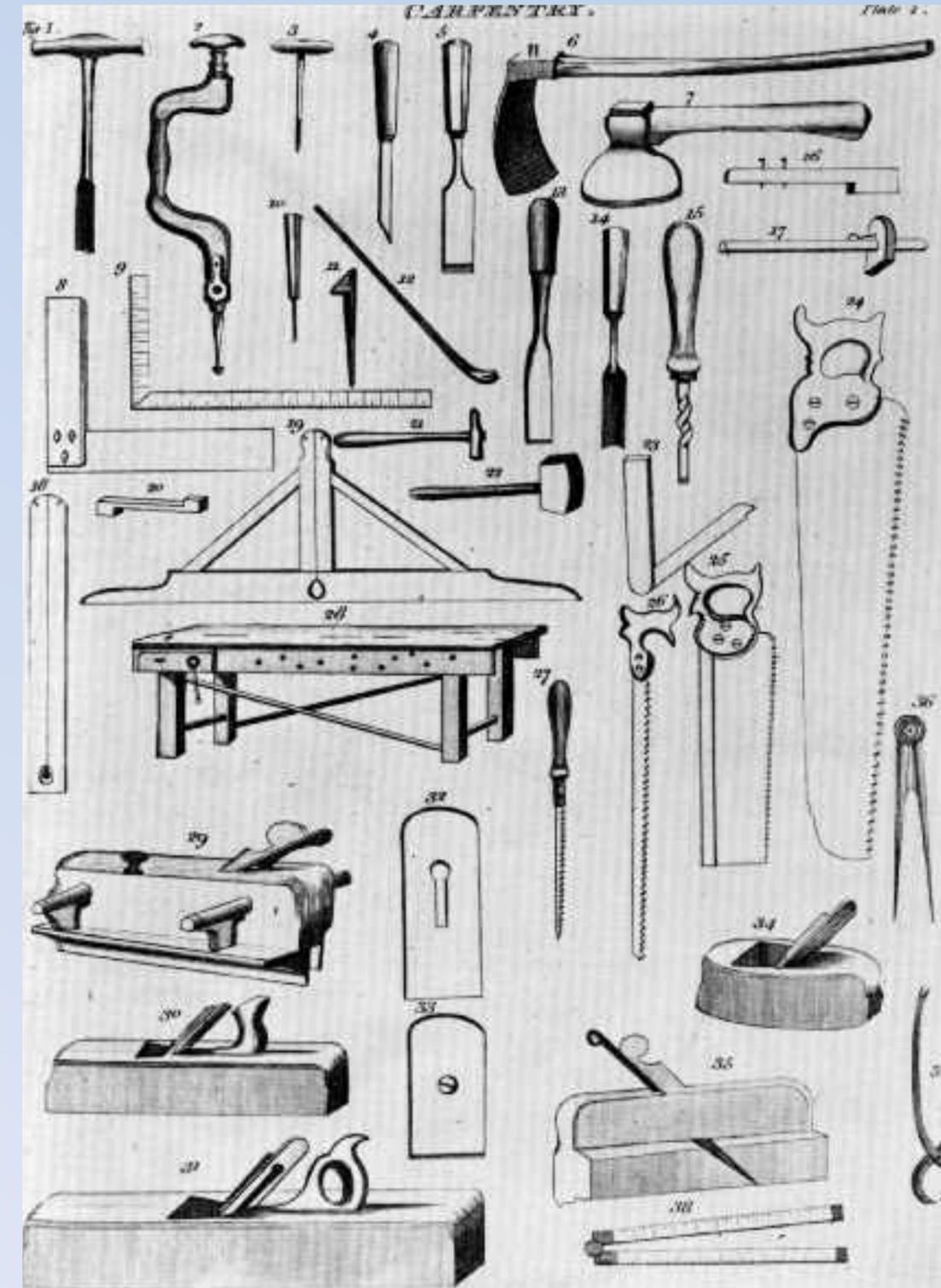
Frank Elavsky



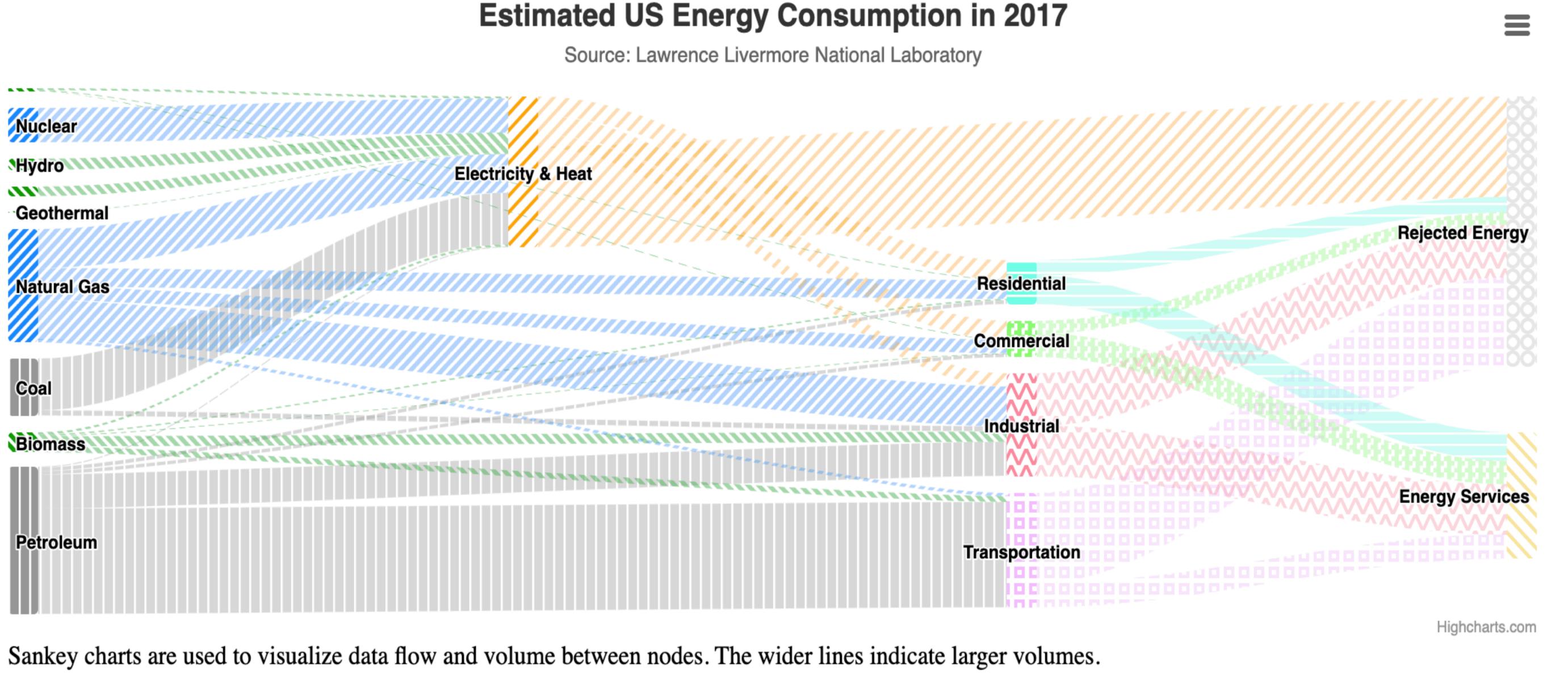
hcii.cmu.edu, axle-lab.com, dig.cmu.edu



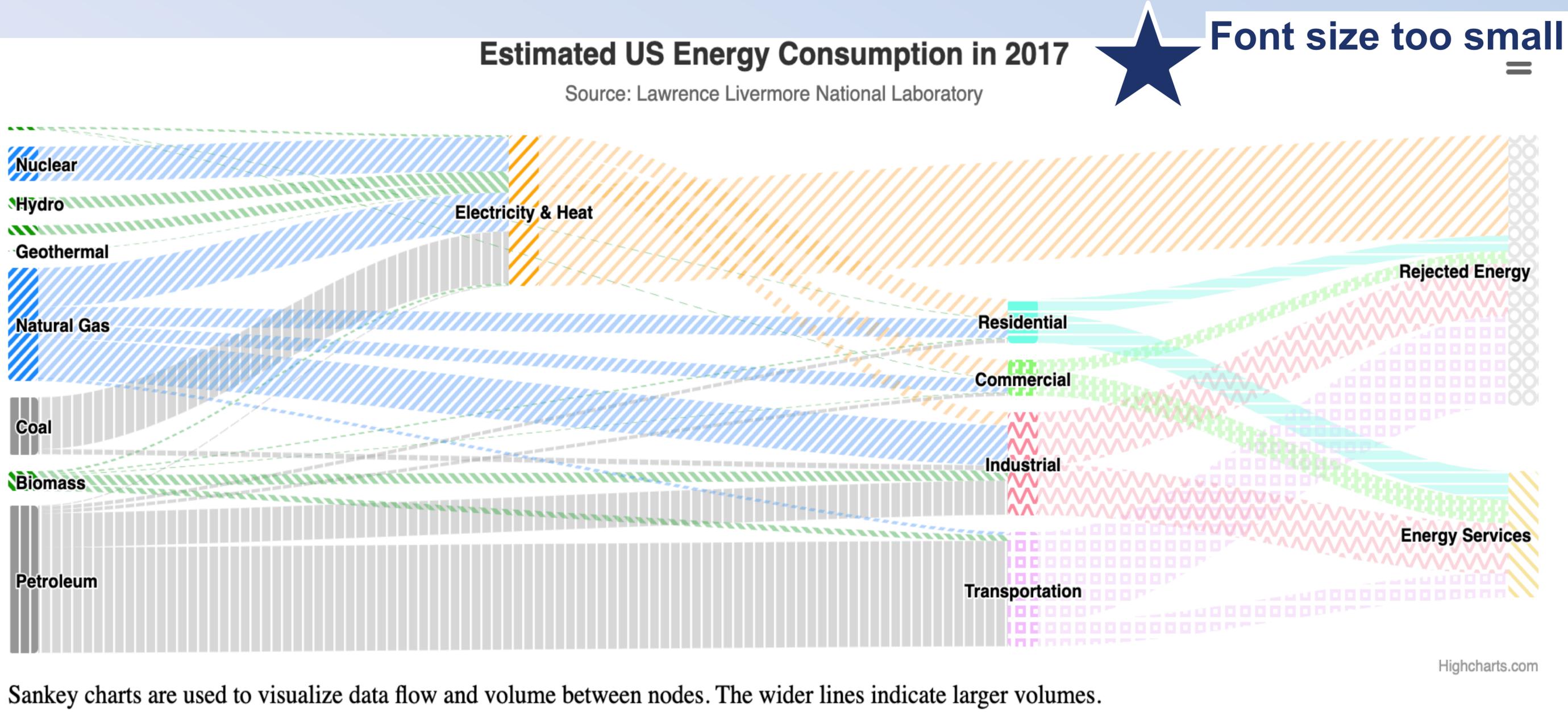
Tools for *agency*:
Freedom to go beyond
the bounds of the tool



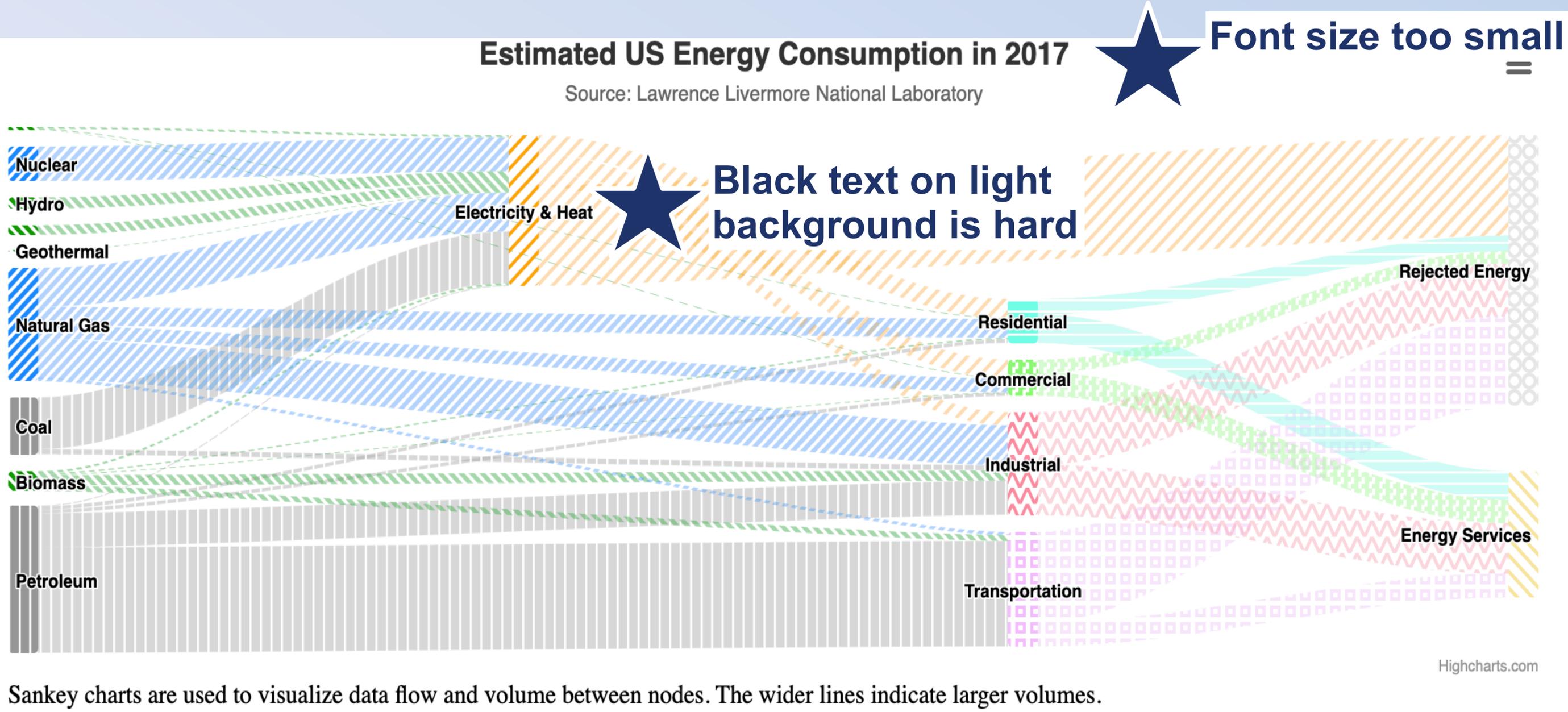
What about this visualization might be a barrier?



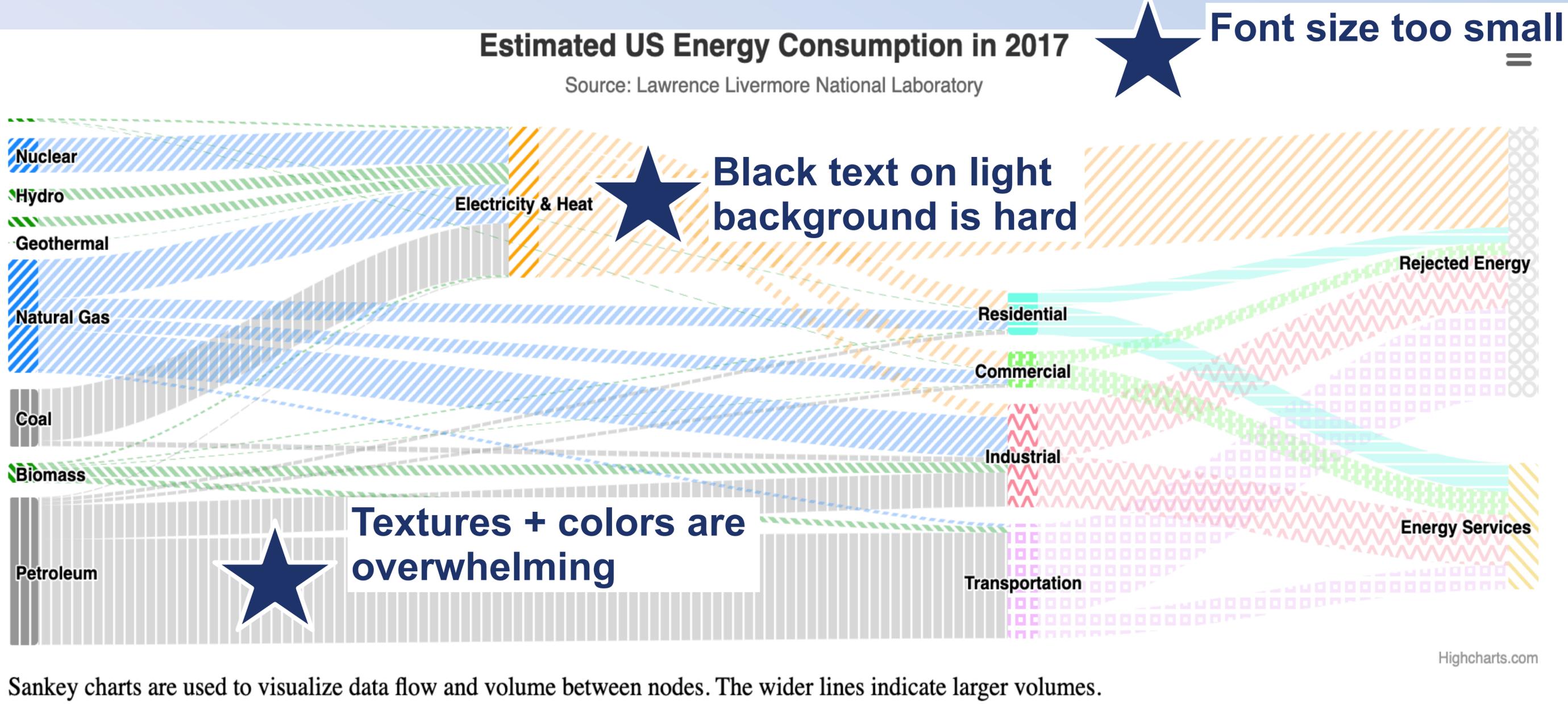
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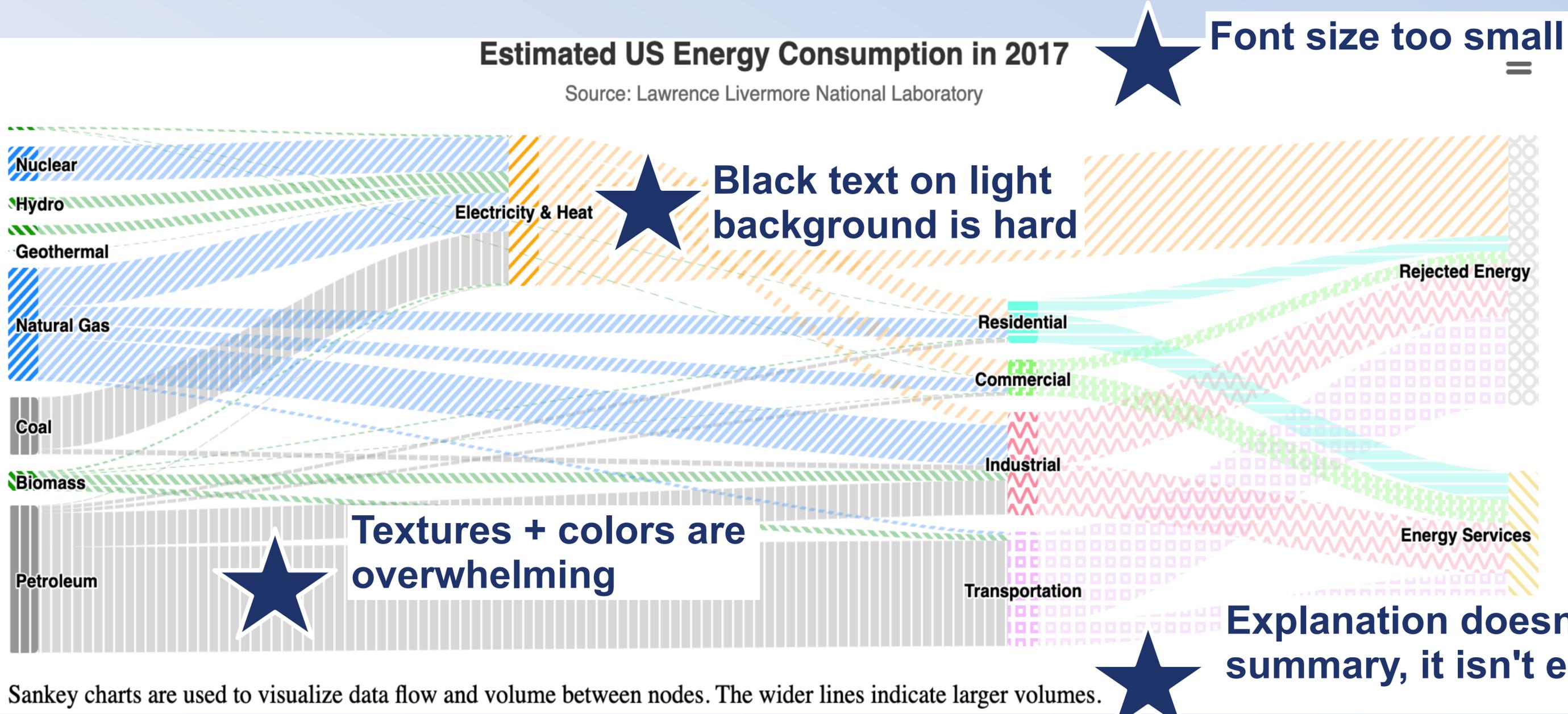
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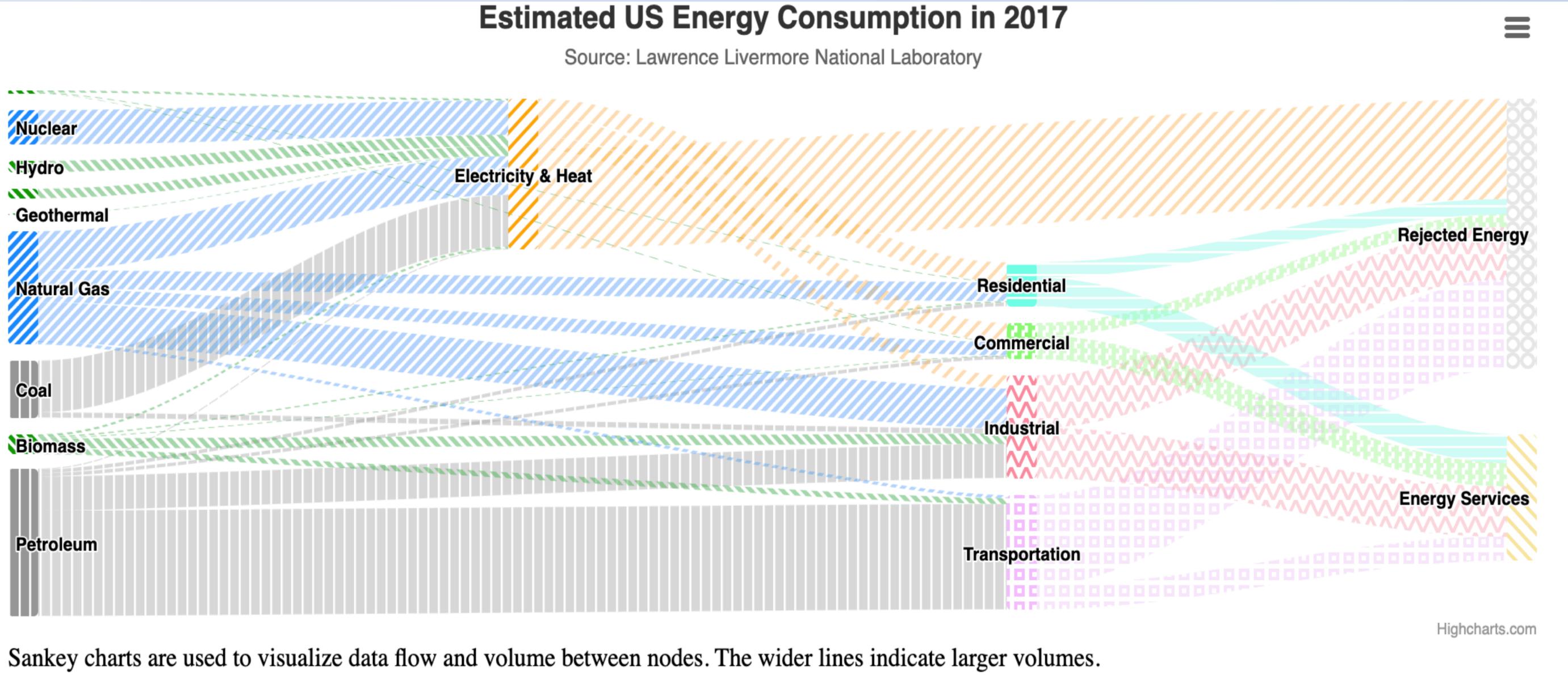
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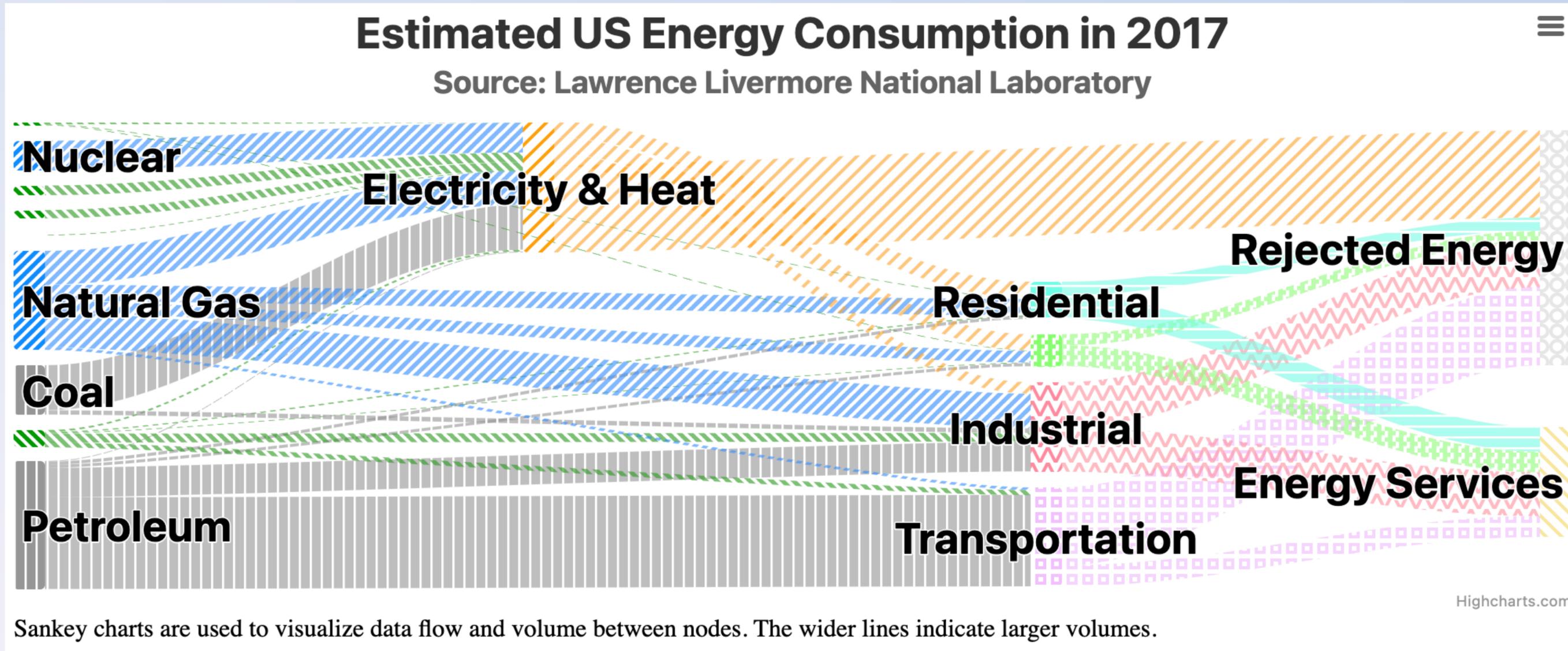
What about this visualization might be a barrier?



Can we fix this?



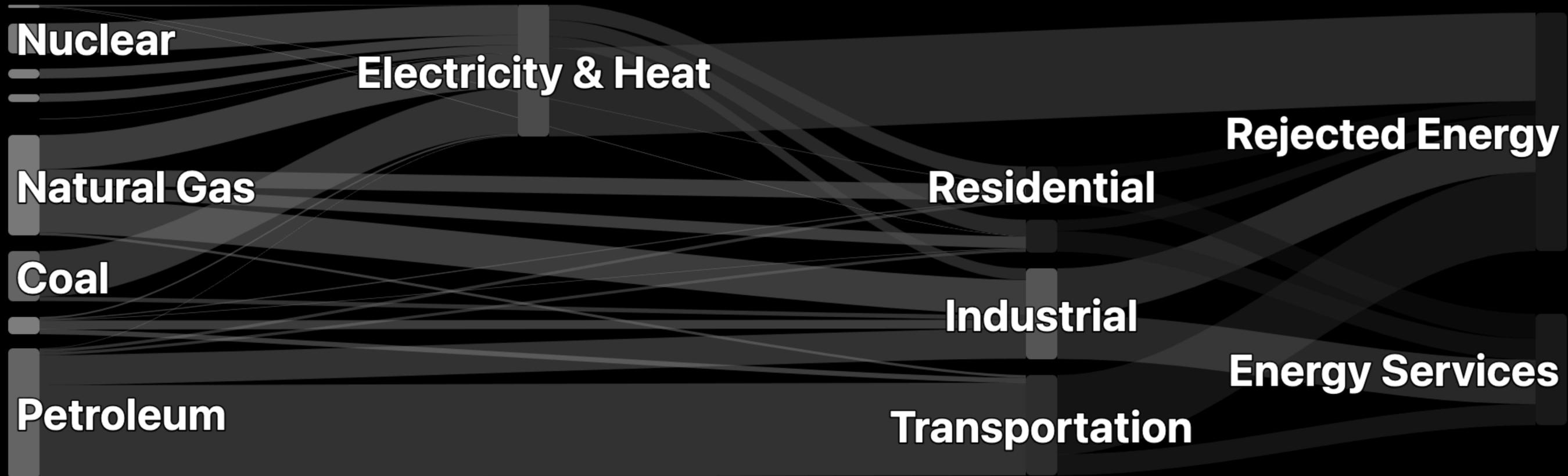
Maybe we can bump up the text size



We can reduce visual complexity too

Estimated US Energy Consumption in 2017

Source: Lawrence Livermore National Laboratory



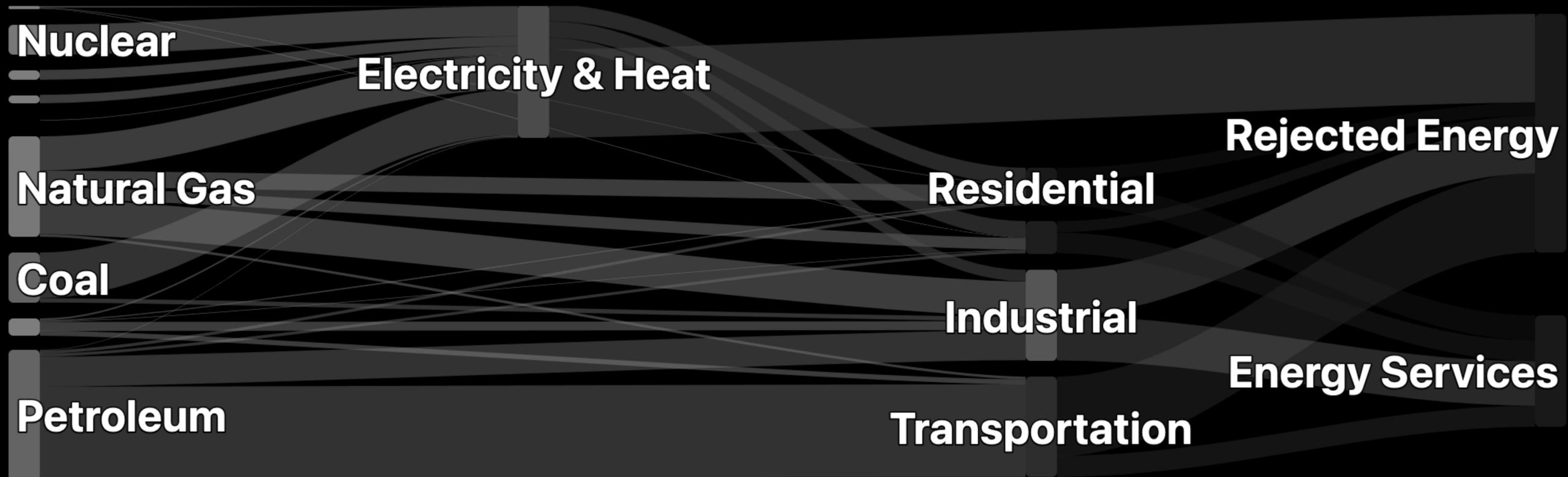
Highcharts.com

Sankey charts are used to visualize data flow and volume between nodes. The wider lines indicate larger volumes.

We can add a more descriptive explanation

Estimated US Energy Consumption in 2017

Source: Lawrence Livermore National Laboratory



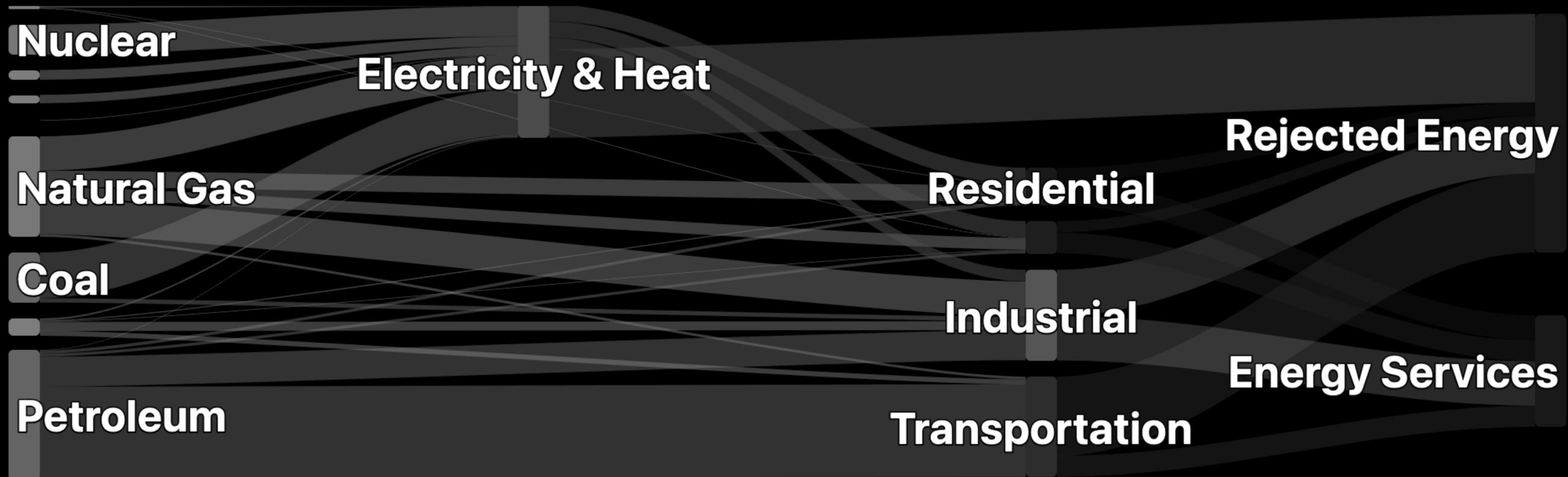
Highcharts.com

Sankey charts are used to visualize data flow and volume between nodes. Visually wider lines indicate larger volumes. This chart is showing energy consumption and types. Interacting with this chart by selecting a node or flow (such as with a click) will update the stacked bar chart below.

Is this the perfect, most accessible design?

Estimated US Energy Consumption in 2017

Source: Lawrence Livermore National Laboratory



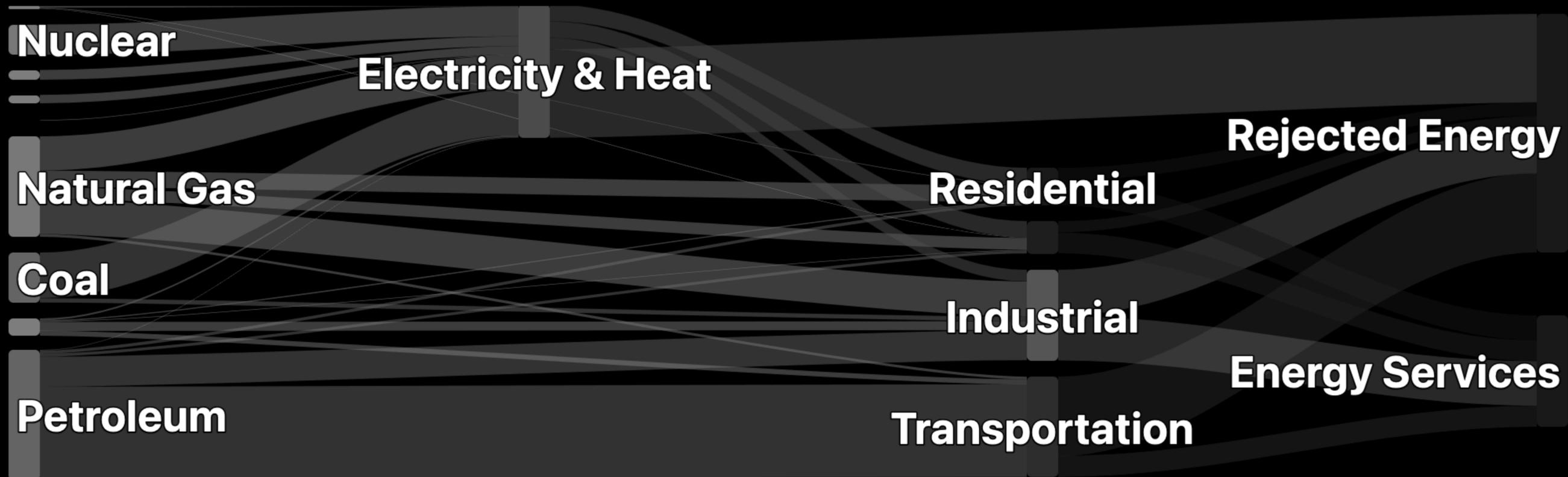
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Sankey charts are used to visualize data flow and volume between nodes. Visually wider lines indicate larger volumes. This chart is showing energy consumption and types. Interacting with this chart by selecting a node or flow (such as with a click) will update the stacked bar chart below.

Bad news...

Estimated US Energy Consumption in 2017

Source: Lawrence Livermore National Laboratory



Highcharts.com

Sankey charts are used to visualize data flow and volume between nodes. Visually wider lines indicate larger volumes. This chart is showing energy consumption and types. Interacting with this chart by selecting a node or flow (such as with a click) will update the stacked bar chart below.

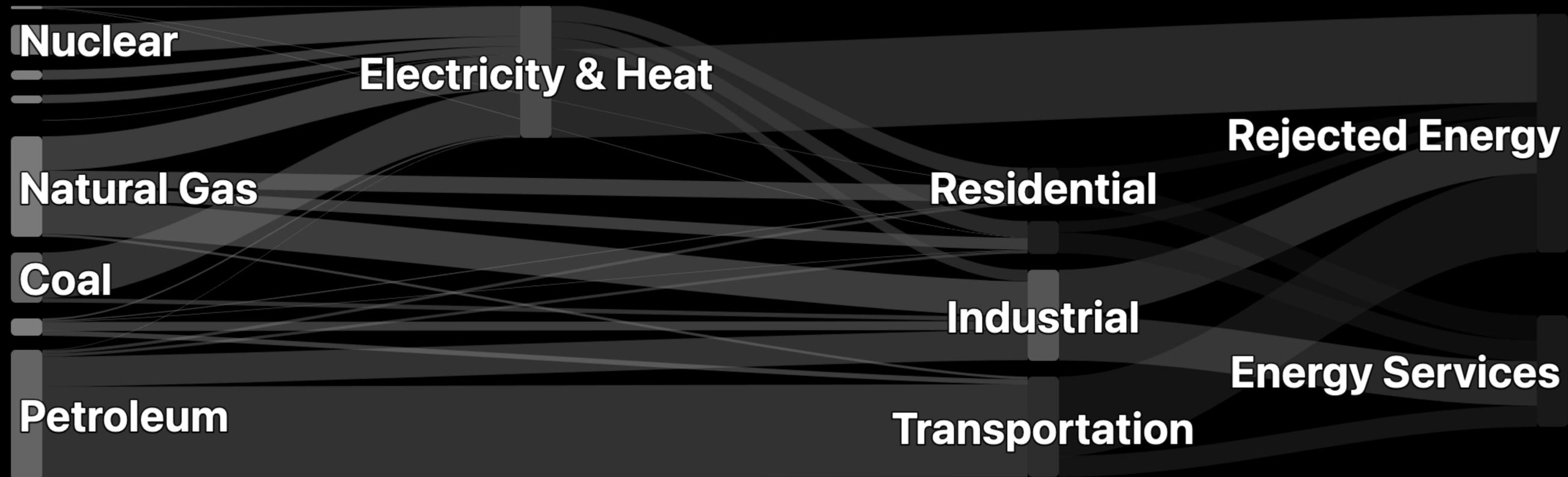
Bad news...



This design has accessibility issues too

Estimated US Energy Consumption in 2017

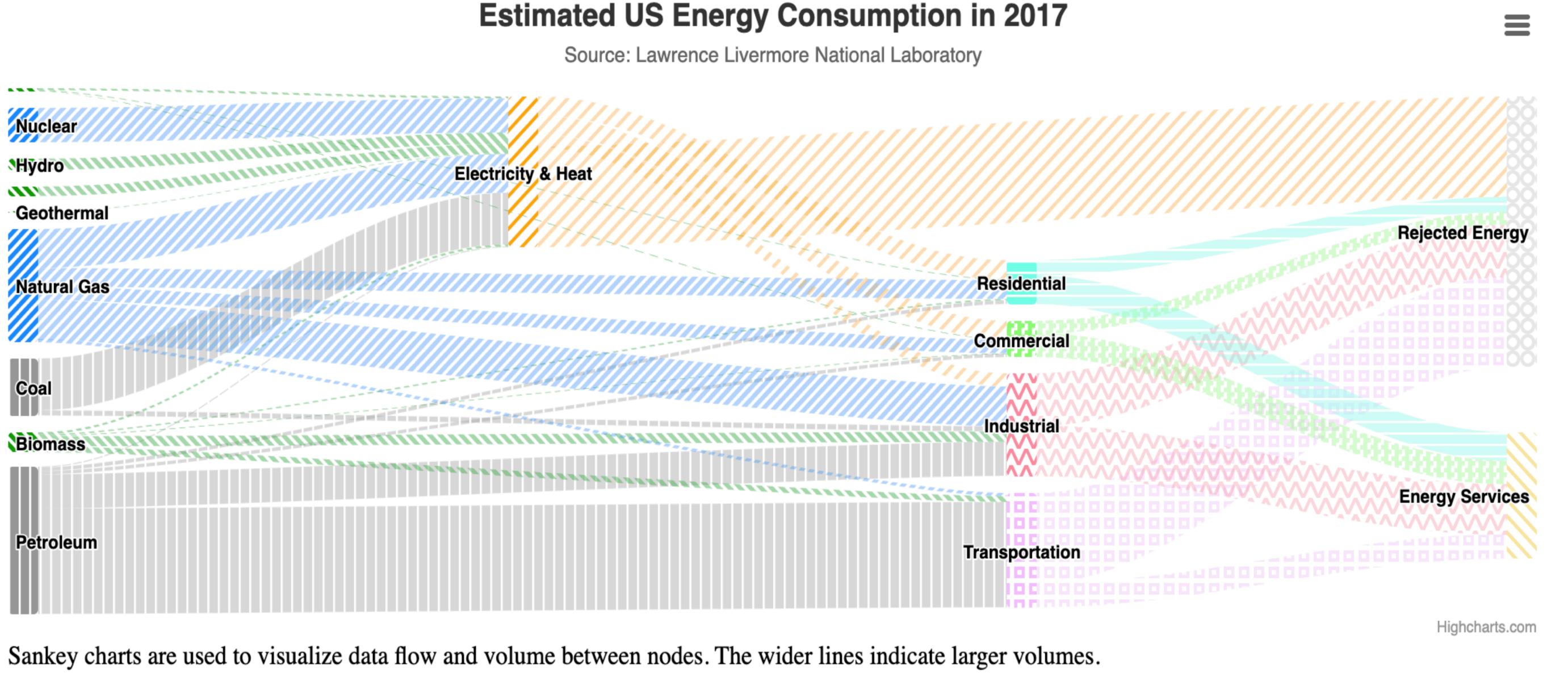
Source: Lawrence Livermore National Laboratory



Highcharts.com

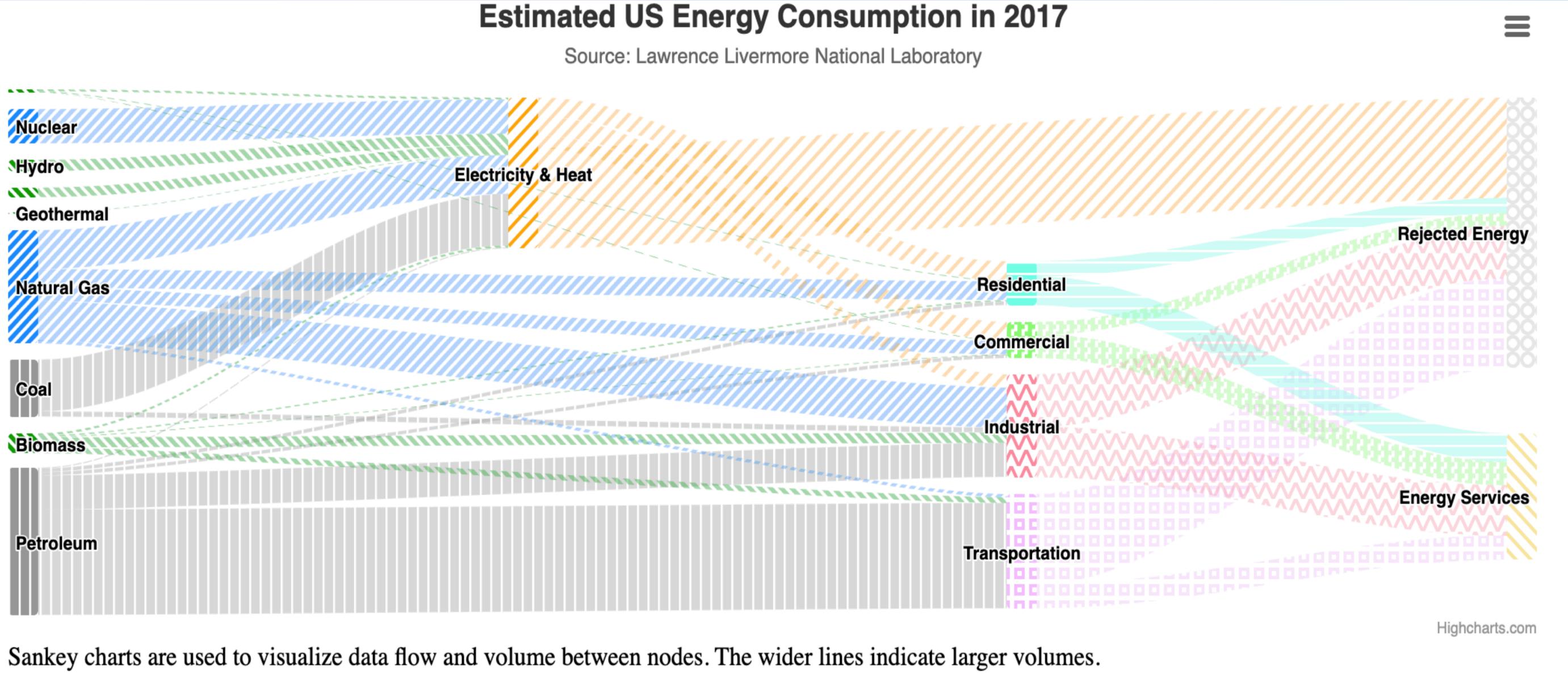
Sankey charts are used to visualize data flow and volume between nodes. Visually wider lines indicate larger volumes. This chart is showing energy consumption and types. Interacting with this chart by selecting a node or flow (such as with a click) will update the stacked bar chart below.

There is no such thing as a single, perfect design



Sankey charts are used to visualize data flow and volume between nodes. The wider lines indicate larger volumes.

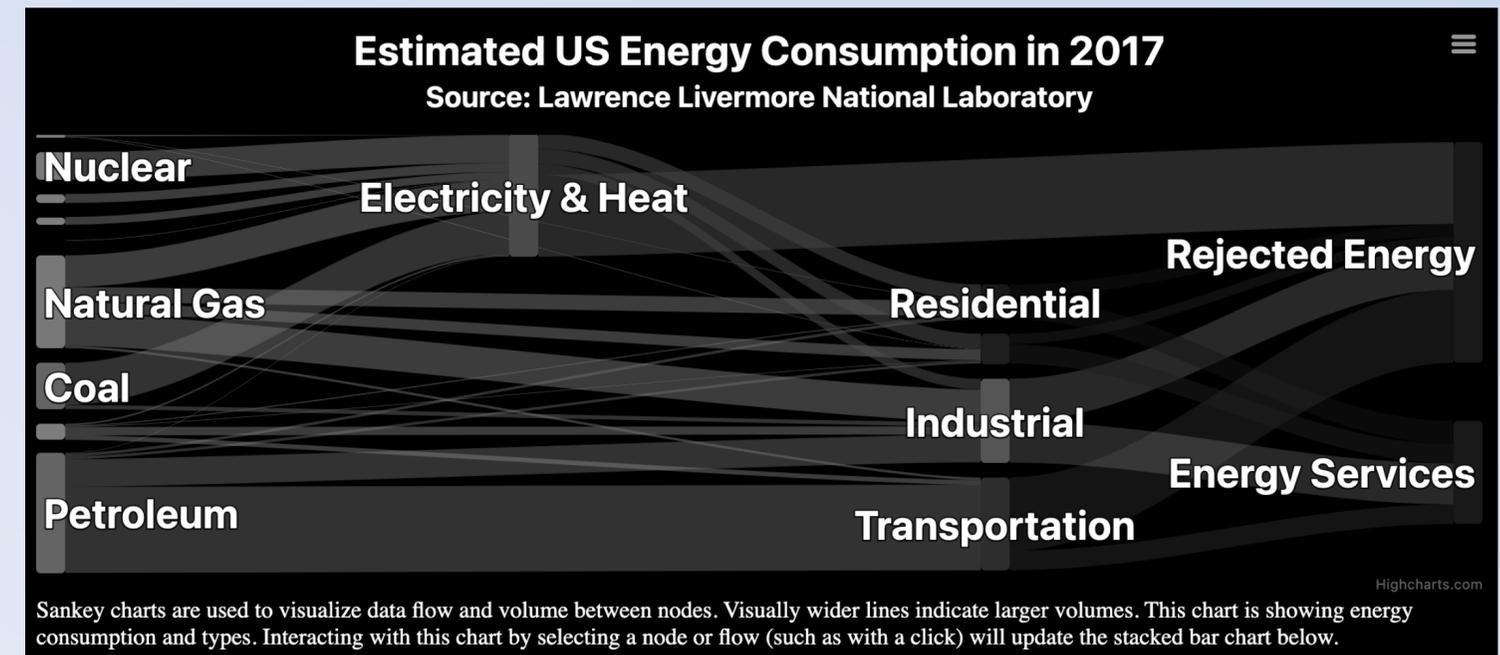
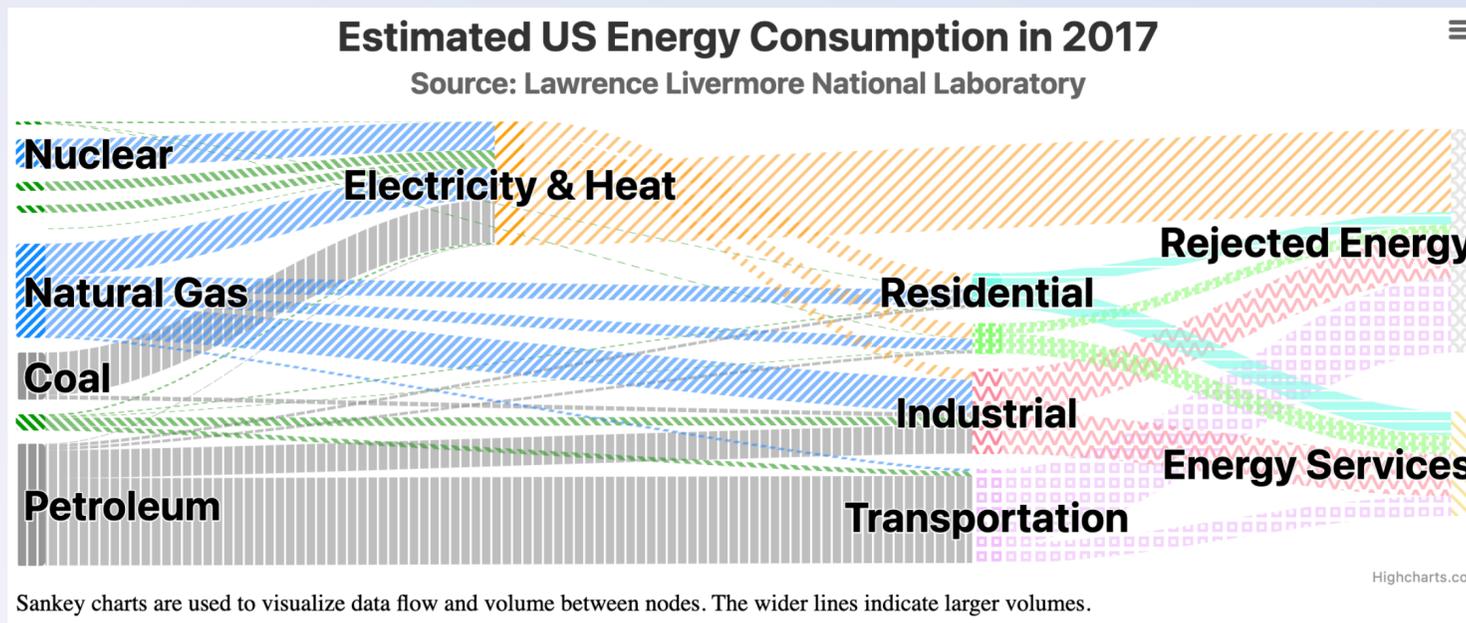
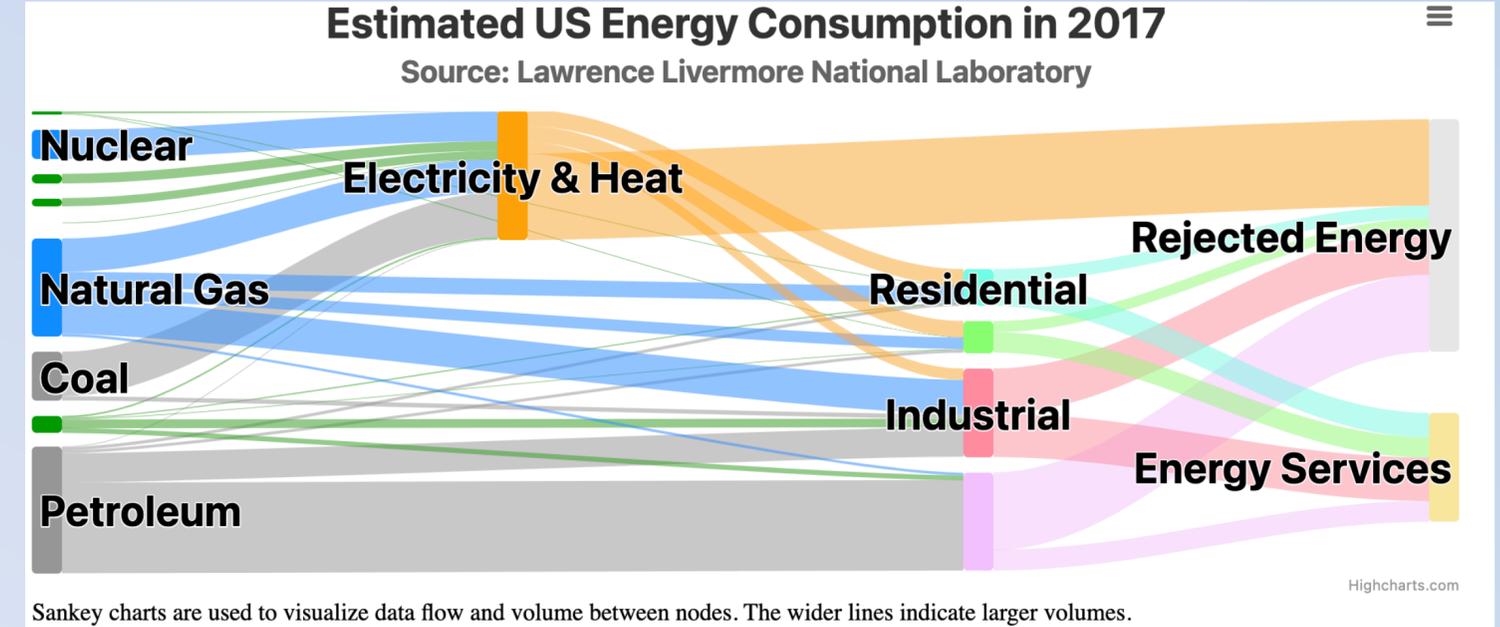
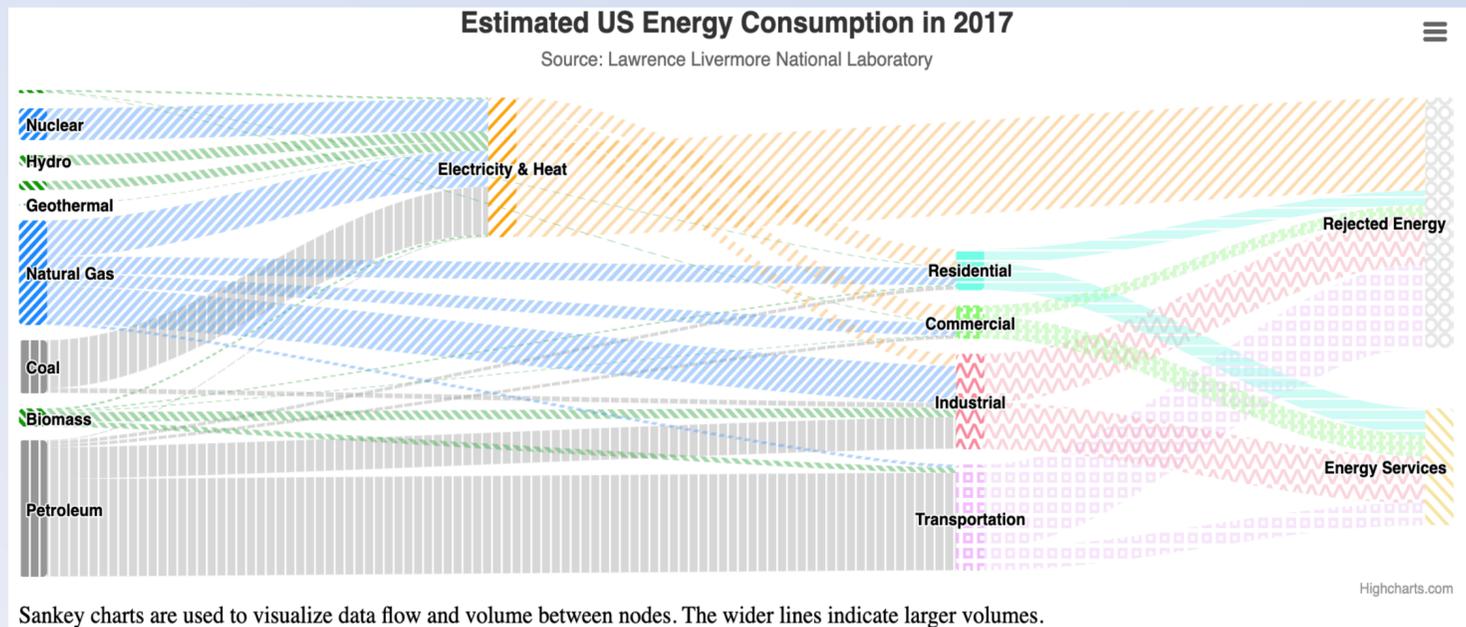
One design *cannot* fit all



Why should our designs be one-size-fits-all?

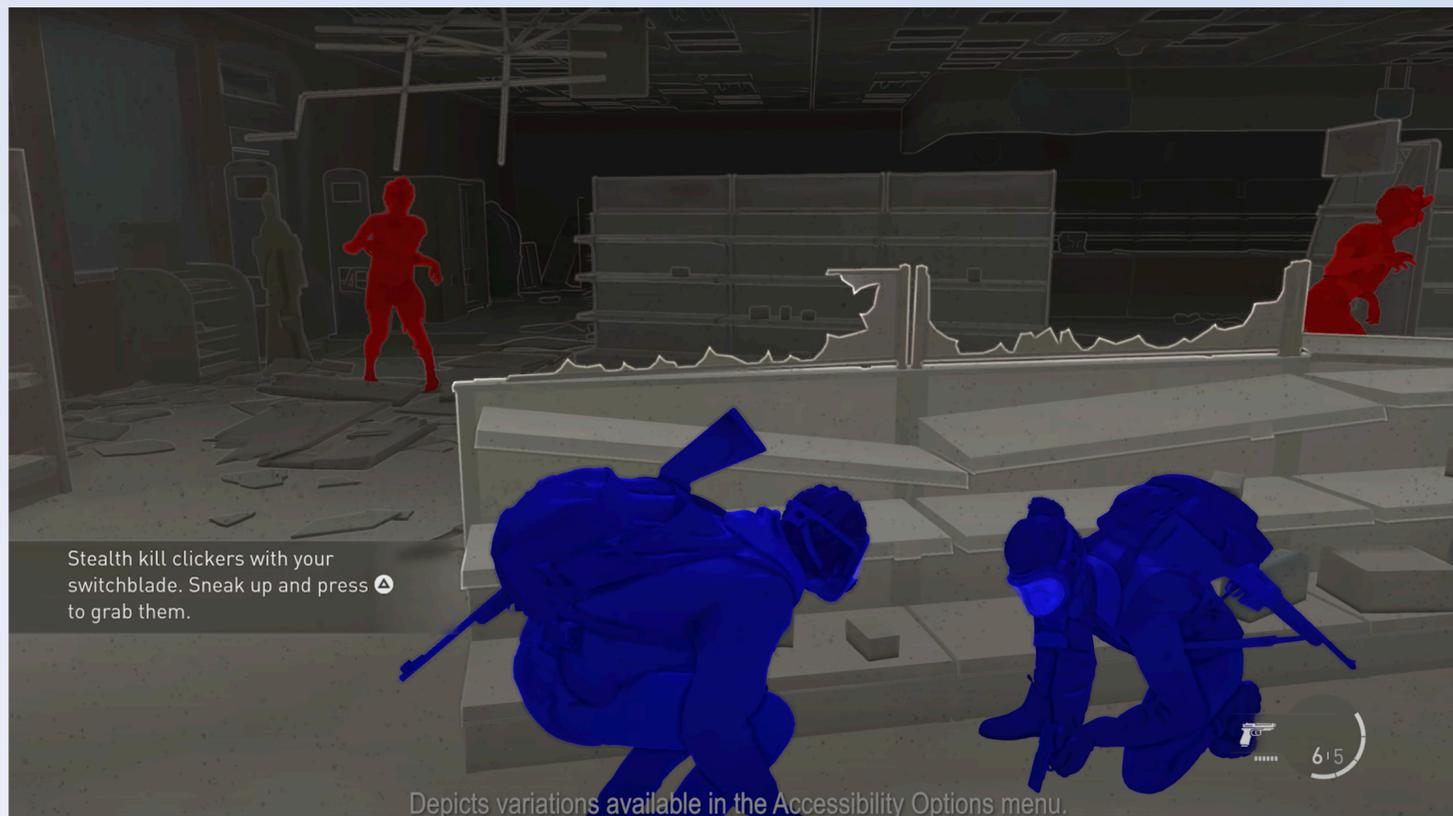


What if we let users personalize?



We have been enabling personalization for years

Video games



The Last of Us 2 has more than 60 settings

Devices and operating systems



"Make it yours" is the motto for Apple's accessibility personalization