GSVS Capstone Research Project, Spring 2022
Climate Crossroads

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Introduction

Climate change is a tangible threat to our society and efforts to reduce its effects are likely to continue to be important — and sometimes contentious — policy fights throughout the 21st century. The consequences of climate change will play a driving role in shaping societies now and in the coming decades. Despite the pressure of this issue and the urgency needed to prevent severe and irreparable damage, there remains a large gap in people's understanding of the climate crisis. The fact of the matter is that climate change is inextricably connected to the social, economic, environmental, and political aspects of our world. In order to make this connection clearer to people we have created an interactive web map that features an interdisciplinary set of climate related data. By providing people with an easy to use tool we are empowering them to interact with climate related information and draw their own conclusions on the interdependence of climate change and other realities. This data visualization project is helping to fill a gap in interdisciplinary climate information in order to help foster cohesion and achieve effective solutions.

Background

The fight against a warming climate will continue to shape the events of the twenty-first century. Human influence on the climate is scientifically clear, yet emissions are still among the highest in history which will result in widespread and potentially devastating impacts on natural and human environments[1]. Addressing this challenge will be tremendously complex but addressing it with urgency is of the utmost importance.

Among the primary and most intuitive impacts of climate change are its effects on the natural environment and biophysical relationships. Human emitted greenhouse gasses redistribute energy from the sun back to the earth which increasingly warms the atmosphere. Warming oceans prove to be a difficult living environment for many organisms. Melting ice sheets threaten arctic populations while simultaneously contributing to global sea level rise. The emissions themselves pollute surrounding air and waterways compromising human health and the overall integrity of these environments[2]. These are just a few items on the extensive list of biophysical impacts of climate change. If action is not taken soon it is likely that many of these effects will lead to irreversible losses in the natural environment.

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[1]IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 1-169.

[2] IPCC, 2014: Climate, 2-3.

More than just affecting the natural environment, climate change threatens the integrity and success of every economy on this earth. The economic impacts of a warming earth span from direct impacts on infrastructure to harder to measure effects such as compromised human health and loss of natural resources. One of the primary drivers of the economic impacts of climate change is the occurrence of externalities. An externality is a cost or benefit of an economic activity that is experienced by an unrelated third party; the external cost or benefit is not reflected in the price of the good or service which can lead to market failures. Furthermore, externalities are the driving force of the tragedy of the commons, a problem of ownership that pervades all environmental goods[3]. In the case of climate change and greenhouse gas emissions, the persistence and accumulation of these externalities function on a global scale and present a risk to all populations on the earth[4]. Another economic impact of climate change is extreme deadweight loss due to the fact that the installation of protective measures against climate change in the built environment are grossly underprovided. This deadweight loss can take the form of damage to infrastructure, compromised human health and safety, and destruction to natural environments. Extreme weather events will continue to occur with increased frequency in coming years which will exacerbate this problem. The loss of biodiversity is among the economic impacts of climate change, though quantifying these in monetary terms is difficult and has been argued to go against the intrinsic value of such resources; thus, this will not be explored further in the paper. To conclude, the economic impacts of climate change prove that urgent action is not only necessary but cost effective in the long term.

Since it first broke into the scene of mainstream discourse in the 1970s, climate change has been a polarizing issue among political parties. Polarization has intensified in recent years serving to further complicate the fight against a warming earth. This occurrence is not only relevant for the divides it creates among citizens and lawmakers, but also for the role it plays in people's perception and understanding of climate related information. As Jerit and Barabas have explored in their paper "Partisan Perceptual Bias and the Information Environment," people have an easier time learning information that aligns with their political party and have a harder time learning information that goes against their political alignment or that paints their party in a negative light[5]. The salience of partisan perceptual bias has been extremely impactful

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[3] "Externality." n.d. Corporate Finance Institute. Accessed April 26, 2022. https://corporatefinanceinstitute.com/resources/knowledge/economics/externality/.

[4] Stern, Nicholas. 2008. "The Economics of Climate Change" 98 (2): 1.

[5] Jerit, Jennifer, and Jason Barabas. 2012. "Partisan Perceptual Bias and the Information Environment." *The Journal of Politics* 74 (3): 672–84. https://doi.org/10.1017/S0022381612000187.

in regards to climate change because it has effectively inhibited certain populations from understanding the scope and urgency of the issue. Additionally, it creates a reinforcing loop, contributing further polarization of the political climate that we see today. Since effective efforts to curb emissions will likely need to occur on both the state and federal level, climate change and politics are inextricably linked. Understanding this relationship is crucial because it helps reveal information on the varying approaches and level of concern about the climate problem that we see today.

The impacts of climate change are not limited to the physical warming of our earth, but rather stretch across disciplines leaving no element of society immune from change. As has been explored, the effects span across multiple domains including the biophysical, economic, social, and political. While many people agree that climate change is an urgent issue, they often lack a framework that effectively integrates scientific action with social realities[6]. In order to combat this problem, more interdisciplinary work is urgently needed.

Why is There a Need for *This* Map?

As has been discussed, the threats of climate change are tangible, dangerous and to a degree, inevitable. In order to mitigate the effect as much as possible, widespread acknowledgment and understanding of the problem is needed. There has been a massive expansion of climate focused information in recent years as climate change continues to prompt attention from multiple disciplines. While this information is on the forefront of modern research there is a gap in accessibility. Climate change research is often buried deep in academic websites or presented in a way that is difficult for the average person to understand. There has been a growing trend led by climate nonprofit organizations and social media accounts to make information appear more casual and approachable though a large gap remains in this regard. The project at hand looks to continue this trend and minimize the information gap between inaccessible academia work and informal climate visualizations. There is a dire need for more readily available information on climate change as this phenomenon continues to threaten nearly every aspect of our society.

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[6] Bhaskar, Roy, Cherly Frank, Karl Georg Hoyer, Petter Naess, Jenneth Parker. 2010. *Interdisciplinarity and Climate Change*. *Academia* 9: 1-254.

Why Create a Map?

The primary goal of this project was to provide a user friendly tool that serves to advance climate knowledge and inspire action among individuals. The complexity of climate change lends itself to even more complexities in effectively communicating information about it. In regards to this, the map at hand aims to present and display the data in a clear and concise manner that is easy for anyone to understand and interpret. Making sense of statistical information uses analytical processes that require cognitive effort[7]. The use of cognitive effort can deter people from interacting with certain mediums; thus, in an effort to reduce cognitive effort we will visualize the data in a way that is inherently easy to make sense of. By employing a map as our tool of choice we are able to easily display spatial information and overlay multiple variables without compromising functionality. As Röber points out in his piece on climate science visualizations, when creating data visualizations there must be a proper balance between aesthetics and functionality[8]. It is important to display variables in a way that complement each other and help tell a story. Maps are able to illustrate statistical information over multiple spatial regions allowing users to compare and contrast regions and variables. This provides the opportunity to interact with the tool in order to find expected consistencies or unexpected discrepancies in the information.

A major challenge with communicating climate change information is that available information is constantly evolving. New studies are always being published as well as new data being made available. Information can become quickly outdated as trends change and new problems arise. There is no easy way to combat this issue that pervades the entire field, however, there are steps that can be taken to prevent the speed with which the relevance of one's work is diminished. Moser points out that engaging across disciplines and building on the growing interdisciplinary approaches is one tactic for research to remain at the forefront of the movement[9]. Instead of focusing on one aspect, an interdisciplinary approach can reveal the interrelatedness of climate change and other key areas of study that have the potential to reveal

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[7] Weber, Elke U. 2010. "What Shapes Perceptions of Climate Change?" *Wiley Interdisciplinary Reviews: Climate Change* 1 (3): 332–42. https://doi.org/10.1002/wcc.41.

[8] Röber, Niklas, Michael Böttinger, and Bjorn Stevens. 2021. "Visualization of Climate Science Simulation Data." *IEEE Computer Graphics and Applications* 41 (1): 42–48. https://doi.org/10.1109/MCG.2020.3043987.

[9] Moser, Susanne C. 2016. "Reflections on Climate Change Communication Research and Practice in the Second Decade of the 21st Century: What More Is There to Say?" *WIREs Climate Change* 7 (3): 345–69. https://doi.org/10.1002/wcc.403.

novel, exciting and relevant relationships. By creating a map we are able to utilize this approach through the displayal of variables that span multiple disciplines. This will help it to evolve and remain a relevant tool that will hopefully continue to provide insights that help advance the field. Another key advantage in creating a map is that it allows for data to be easily updated to maintain relevance if one desires. While there are no current plans for regular updating on the map, the advantage remains nonetheless.

The final reason for choosing to construct a map is that it allows us to neutrally frame our information. Frames in communications are words, symbols, phrases, or images that highlight or suggest potentially relevant considerations towards any subject[10]. Some people have argued that eliciting emotions such as positivity and hopefulness instead of negative ones such as fear should be the focus of climate change communications; however, Chapman et al. challenge this assumption by discussing the complexities of emotions and arguing that certain messages may elicit different feelings in different populations[11]. Based on this argument it is clear that framing climate messages with the hopes of eliciting certain emotions can potentially be a misleading path especially when navigating a highly polarized political environment. The suggestions that Bolsen and Shapiro make in their paper on effectively communicating in a polarized environment provides more insight to this discussion. Some of the suggestions they make are to present information in a way that will encourage greater consensus and cooperation, frame it in a way that increases people's efficacy of action, and use credible sources[12]. After considering these insights, creating a map seemed to meet all the requirements for meaningful and useful communication. It allows us to frame the situation neutrally by simply displaying data and allowing individuals to draw their own conclusions. This in turn has the potential to advance consensus and possibly cooperation among the population. It also has the potential to increase people's efficacy of action by presenting them with the information and allowing them to act on it in a capacity that fits into their life.

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[10] Bolsen, Toby, and Matthew A. Shapiro. 2018. "The US News Media, Polarization on Climate Change, and Pathways to Effective Communication." *Environmental Communication* 12 (2): 149–63. https://doi.org/10.1080/17524032.2017.1397039.

[11] Chapman, Daniel A., Brian Lickel, and Ezra M. Markowitz. 2017. "Reassessing Emotion in Climate Change Communication." *Nature Climate Change* 7 (12): 850–52. https://doi.org/10.1038/s41558-017-0021-9.

[12] Bolsen, "The US News Media," 156.

Other Maps

There are several other web maps that have been created to display climate information, however, rarely do these tools employ an interdisciplinary approach to the climate solution. A key drawback to this is that they do not provide people with the necessary information on the many underlying relationships that are at the core of the climate crisis. The table below provides information on the currently existing tools in this area:

Existing Tools	Interactive?	Multiple categories?	Ease of Use	Comment
Yale Climate Opinion Maps 2020 - Yale Program on Climate Change Communication	Yes	Not at one time	Poor zoom / search functionality	No overlay of data to view multiple categories at once
Visualizations – Climate Prediction – Geophysical Fluid Dynamics Laboratory (noaa.gov)	No	No	Easy to use but difficult to understand	Not interactive
Climate in the United States | USAFacts	Somewhat	No	Relatively easy	No intersectionality
Interactive maps of global climate information | American Geosciences Institute	Yes	No	Difficult	Maps one set of data at a time
EnviroAtlas Interactive Map | United States EPA	Yes	Yes	Difficult	Very difficult to use; requires a 'tutorial'
IPCC WGI Interactive Atlas (Simple)	Yes	Yes	Relatively Easy	Only maps environmental factors

Each of these tools provides valuable insight into climate change, however, as demonstrated in the table there are critical places where they are lacking. The map we have created is interactive, displays multiple categories, and provides easy zoom and search functionality. It effectively fills the existing gaps in which we found these tools to be lacking.

Methods

Data Preparation

To support our goal of visualizing climate data intersections, much effort was devoted towards preparing the data such that it could be visualized intuitively with any noteworthy intersections highlighted. Our final draft of the map includes 14 data layers from the EIA, Yale, StatesAtRisk, the EPA, and C2ES. Upon completed preparation, data layers consist of table data specifying the geography name (i.e. VA, TX, census ID 27053100200) and a value for the given topic (i.e.

5%, 14.41BTU); as well as the spatial file necessary for the Mapbox SDK to appropriately draw the polygon onto the map. In our case, most data downloads came in CSV or XLSX format without any spatial attributes attached. This required that we performed the “Add Join” function within ArcGIS Pro between the downloaded table data and geographic shapefile datasets that we collected from the US Census website, identifying the geography name field as the target field for this operation. While this is quite a common spatial analysis, we struggled in this step as our QGIS application for some reason wasn’t working and ArcGIS Pro is only available on Windows computers, plus the Scholar’s Lab computers located in Alderman Library were unavailable. Ultimately, we were able to secure a computer with ArcGIS Pro and perform the spatial analysis necessary for each data layer, which we then uploaded to MapBox Studio to create our custom style for this map.

With data readied, we uploaded them to Mapbox Studio in order to quickly adjust symbology settings. We used care to apply color to geographies according to an unbiased and fair representation of their values in each topic. We chose a consistent red - transparent - green color gradient for each layer such that layers could be individually investigated or stacked on top of each other with intuitive colors.

Having completed all formatting, preparation, and symbology for our layers, we constructed a custom map using the Mapbox GL JS library, html, and Github. Using code snippets from the Mapbox GL JS API reference, we were able to quickly incorporate useful features including a toggle menu, legend, hover pop-ups, navigation bar, labels, a title, and more. The final map is hosted for free on Netlify Hosting.

The Map

This section will include a user-friendly explanation of the map. It will give a brief overview of each of the categories and an in depth look at each individual layer of the map. The purpose of this is to provide individuals with necessary background information on why each data set was selected.

Layers

In order to provide users with the opportunity to arise at meaningful conclusions we carefully selected data sets that spanned a variety of topics. This also assured that we were providing the necessary information to create an interdisciplinary tool. We chose to organize the data sets into various categories to both ensure that we had gathered a diverse enough range and to further

facilitate user understanding of the data presented. The following sections contain useful background information on each of the four categories as well as an in depth look at the individual layers within them.

The Legend

In order to facilitate the use of the map and reduce clutter, a single legend was created and applied to the data presented on each individual layer. The legend is in gradient form with the color red and the label “low score” on the left side and the color green and the label “good score” on the right side. This means that anything displayed in red indicates a bad action or occurrence, contributing to an overall low score on the state’s efforts to curb climate change. The opposite is true for attributes depicted in green. The colors red and green were chosen because of their typical, often automatic, association with ‘bad’ and ‘good’ respectively. Ideally a more comprehensive legend would have been included for each layer, but given the number of topics that were included this would have resulted in a cluttered and confusing map. Thus, the decision to include one unified legend was deemed more beneficial.

Beliefs/Perceptions Layers

The first category included data sets that looked at people's beliefs and perceptions about climate change. Despite the growing scientific evidence that the earth is warming as a result of human activities, there is still a lack of consensus among citizens regarding this occurrence. The US National Research Council committees state that perception of the global phenomena climate change is a crucial contributor to both climate related problems and potential solutions because of the potential divergence that these perceptions create among the population[13]. Thus, we found it imperative to include data on the current state of climate beliefs in the United States in order to better understand where there might be contention. This category primarily included data sourced from the Yale Climate Opinion Maps[14]. This data source is a national survey with a sample size of >28,000 adults across the United States and spanned a variety of climate related topics. The topics chosen to be included in this category are:

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[13] Weber, Elke U. 2010. “What Shapes Perceptions of Climate Change?” *WIREs Climate Change* 1 (3): 332–42. https://doi.org/10.1002/wcc.41.

[14] “Yale Climate Opinion Maps 2020.” Yale Program on Climate Change Communication, October 19, 2021. https://climatecommunication.yale.edu/visualizations-data/ycom-us/

- Belief that climate change is happening
- Belief that climate change is happening from human activities
- Belief that climate change will affect me personally
- Belief that climate change will affect people in the United States
- Belief that corporations should do more to prevent climate change
- Belief that the president should do more to prevent climate change

Each of these layers will be explored in the following sections.

Climate Change is Happening

This layer depicts individuals' belief that climate change is happening. As mentioned above, people's understanding of the climate crisis is a critical contributor to how this problem is addressed. Thus, we found it necessary to provide users with information on which populations have the highest belief that there is a problem in the first place. This is critical background information because it can help inform conclusions on how belief correlates to actual emissions or states with policies enacted. States with a high percentage of the population believing in climate change are depicted in green, while states with a low percentage of the population are depicted in red. A screenshot of this layer is displayed below:

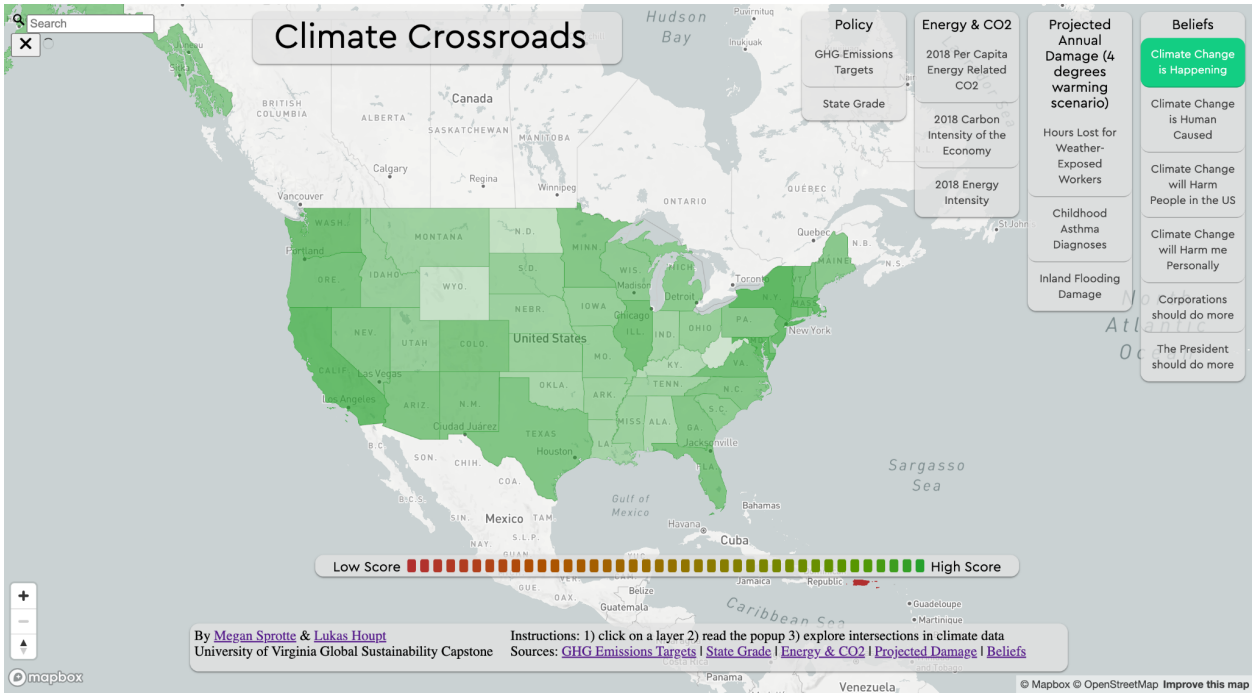

Figure 1: Belief that Climate Change is Happening
(Source: "Yale Climate Opinion Maps 2020." Yale Program on Climate Change Communication, October 19, 2021. https://climatecommunication.yale.edu/visualizations-data/ycom-us/.)

Climate Change is Happening from Human Activities

In contrast to the information presented above, this layer shows percentages of the population that believe climate change is happening as a result of *human activities*. There are large discrepancies in the media about the root cause of climate change, and scientific findings are often contested; however, if people can not agree on a root cause of climate change, then efforts to prevent it are likely to be in vain. This layer was included to show the general feeling of human involvement in climate change across states in the US. States with a high percentage of the population believing in human caused climate change are depicted in green, while states with a low percentage of the population are depicted in red. A screenshot of this layer is displayed below:

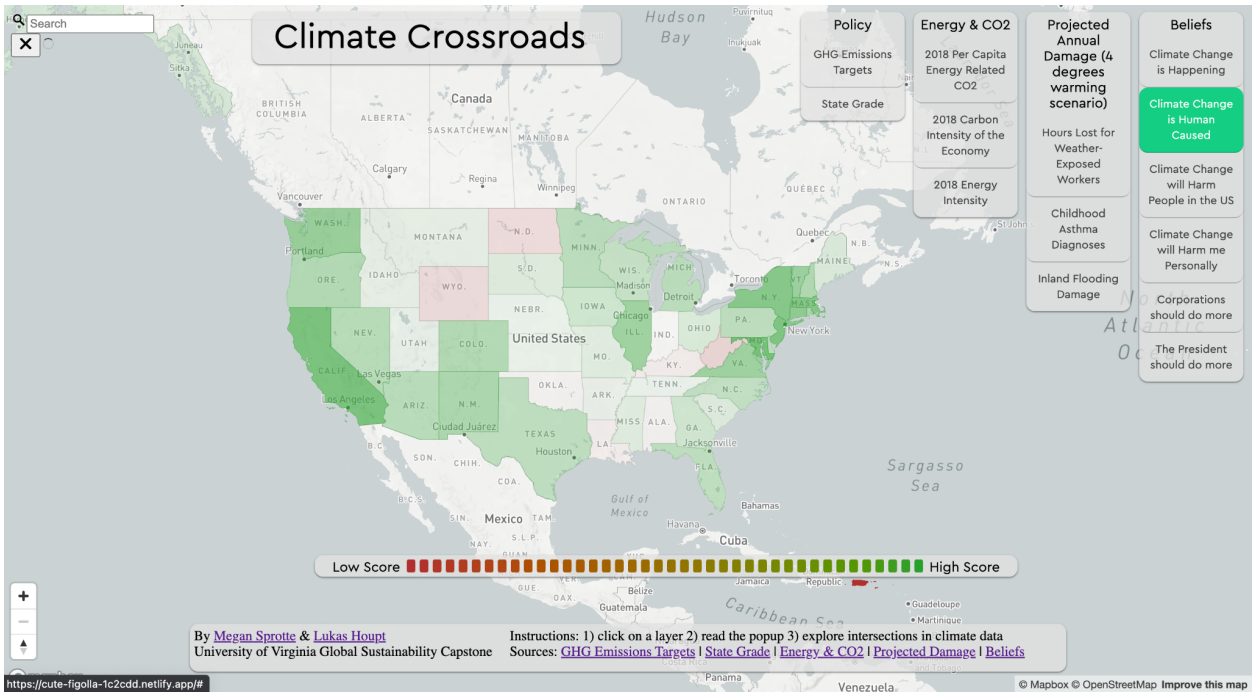

Figure 2: Belief that Climate Change is Happening from Human Activities
(Source*:* "Yale Climate Opinion Maps 2020." Yale Program on Climate Change Communication, October 19, 2021. https://climatecommunication.yale.edu/visualizations-data/ycom-us/.)

Climate Change Will Harm People in the United States

This layer depicted the percentage of the population that believed that climate change will harm people in the United States. This layer was chosen to see if there are any discrepancies between how people perceive climate change threatens themselves versus others. We thought

it was important to see if people themselves felt they were safe from climate change, or if they believed the country as a whole was immune from harm. States with a high percentage of the population believing that climate change will harm people in the US are depicted in green, while states with a low percentage of the population are depicted in red. A screenshot of this layer is depicted below:

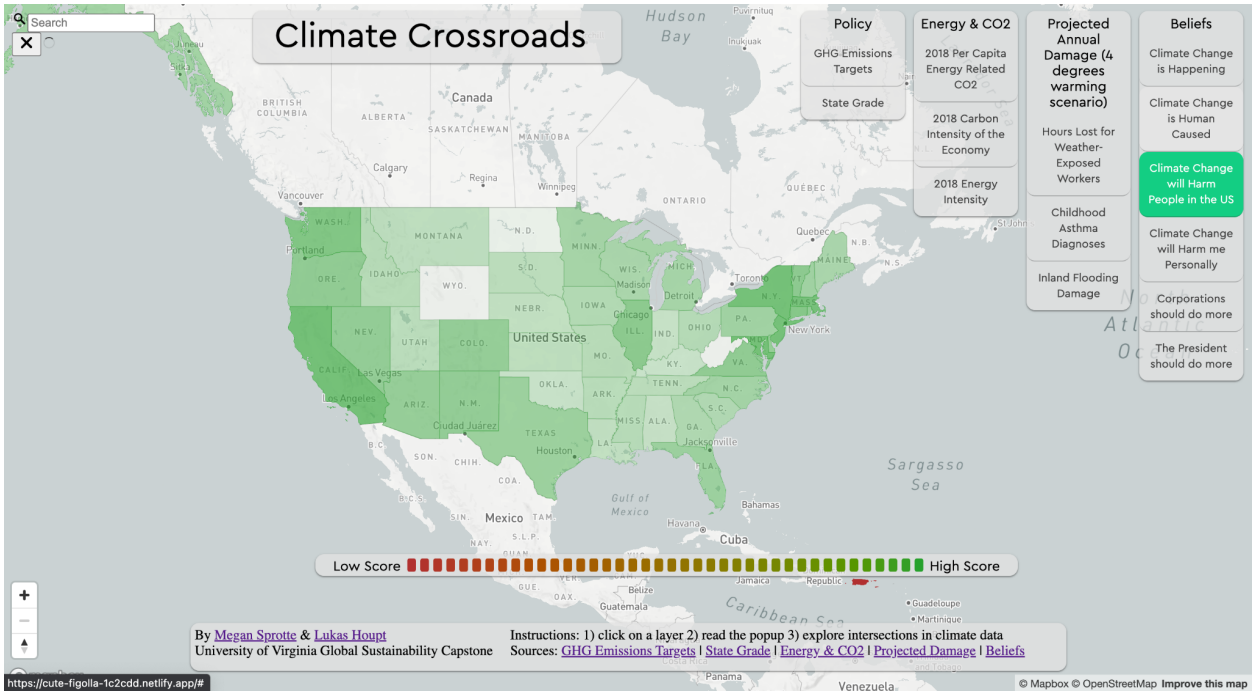

Figure 3: Belief that Climate Change Will Harm People in the United States
(Source*:* "Yale Climate Opinion Maps 2020." Yale Program on Climate Change Communication, October 19, 2021. https://climatecommunication.yale.edu/visualizations-data/ycom-us/.)

Climate Change Will Harm Me Personally

This layer depicted the percentage of the population that believe that climate change will harm them personally. This layer was included to help visualize the level of perception of threat across the United States, and to see which populations feel they are the most vulnerable. Perception of threat is an important building block for both understanding of and action against climate change. States with a high percentage of the population believing that climate change will harm them are depicted in green, while states with a low percentage of the population are depicted in red. A screenshot of this layer is depicted on the following page:

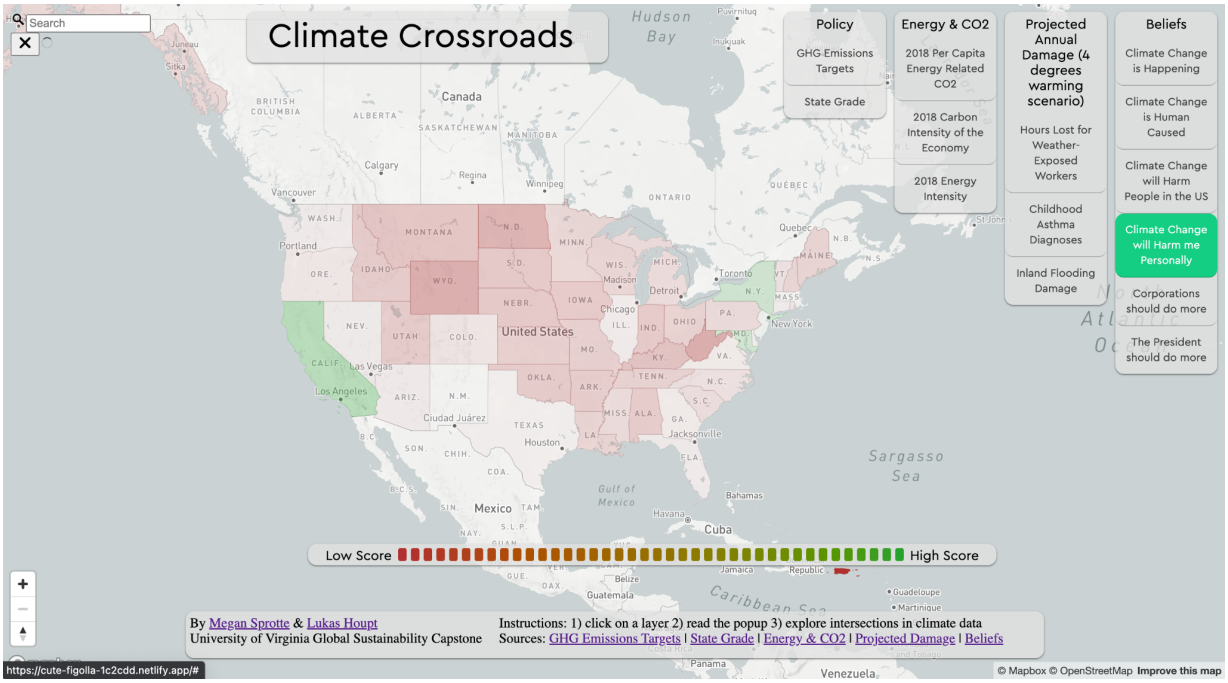

Figure 4: Belief that Climate Change Will Harm Me Personally
(Source*:* "Yale Climate Opinion Maps 2020." Yale Program on Climate Change Communication, October 19, 2021. https://climatecommunication.yale.edu/visualizations-data/ycom-us/.)

Corporations Should Do More

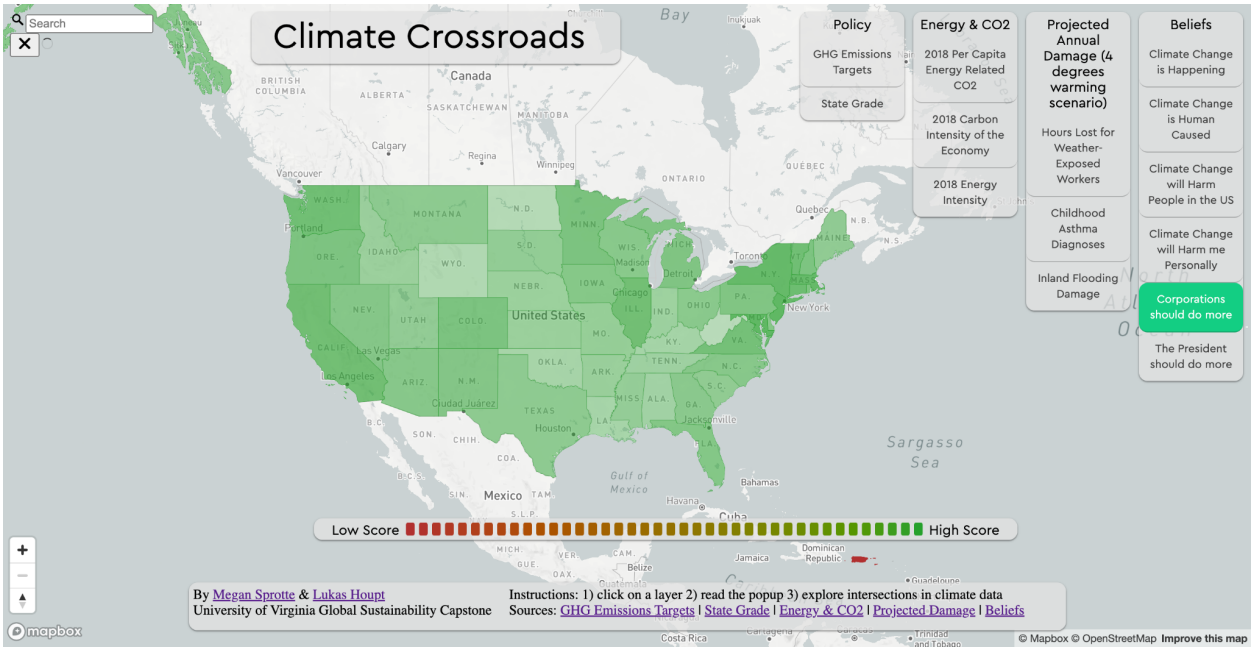

Figure 5: Belief that Corporations Should Do More to Address Climate Change
(Source*:* "Yale Climate Opinion Maps 2020." Yale Program on Climate Change Communication, October 19, 2021. https://climatecommunication.yale.edu/visualizations-data/ycom-us/.)

This layer depicts people's belief that corporations should be doing more to address climate change. This layer was included to provide context on where US citizens are placing the blame for climate change and where they expect to see changes. States with a high percentage of the population believing that corporations should do more to address climate change are depicted in green, while states with a low percentage of the population are depicted in red. A screenshot of this layer is depicted above.

The President Should do More

The final layer for this category was people's belief that the president should be doing more to address climate change. It again provides insight into who citizens think should be at the forefront of limiting its effects. States with a high percentage of the population believing that the President should do more to address climate change are depicted in green, while states with a low percentage of the population are depicted in red. A screenshot of this layer is depicted below:

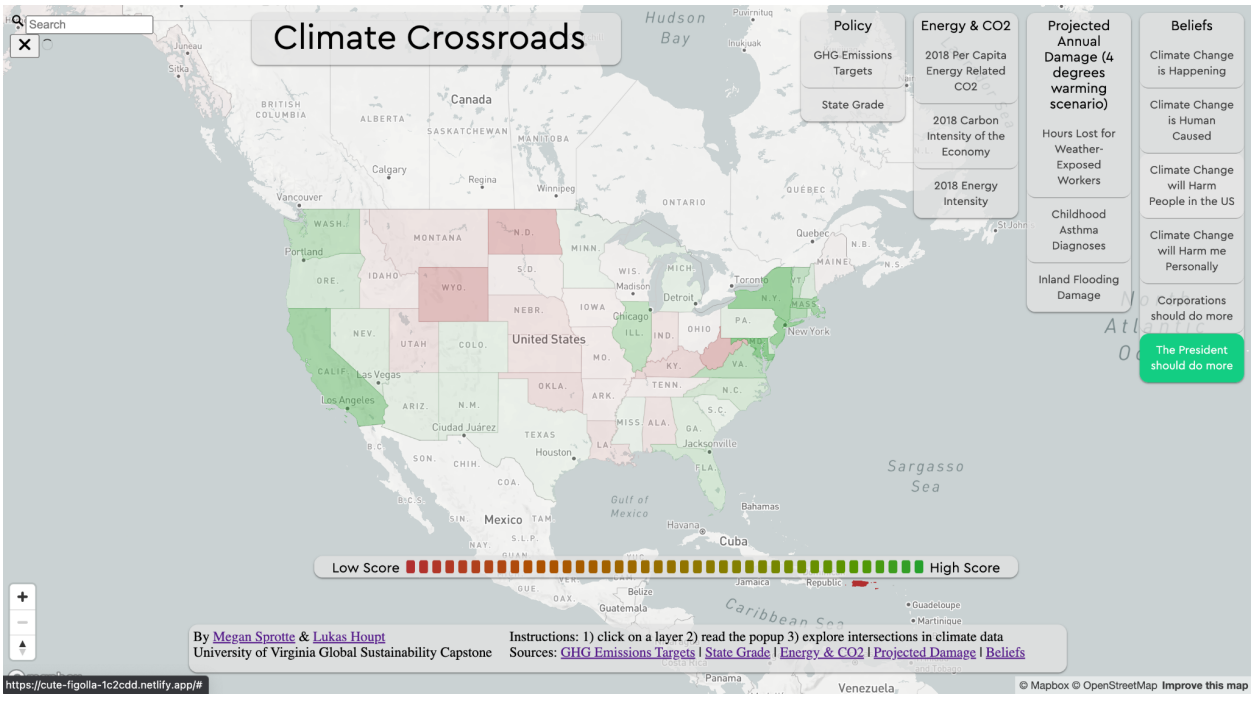

Figure 6: Belief that the President Should Do More to Address Climate Change
(Source*:* "Yale Climate Opinion Maps 2020." Yale Program on Climate Change Communication, October 19, 2021. https://climatecommunication.yale.edu/visualizations-data/ycom-us/.)

Policy Layers

The second category of data that we included was policy. These layers primarily looked at state actions that have been taken either in prevention or response to climate change. Policy has become an important method of addressing climate change in the United States on the federal level, though that does not take away from the importance of action on the state level as well. By presenting this information in the map it will allow the user to draw connections and conclusions between enacted policies and subsequent environmental realities. Furthermore, it provides insight into which states are taking the most aggressive steps to address this global phenomena. The data presented in this category are: State Level Greenhouse Gas Emissions Targets[15] and State Grade on Preparedness Report card[16]. These will be explained in greater detail in the following sections.

Greenhouse Gas Emissions Targets

This layer depicts the presence or absence of greenhouse gas emissions standards among states in the United States. A greenhouse gas emissions standard is a goal to reduce emissions within a state by a certain amount by a predetermined date[17]. Limiting greenhouse gas emissions is critical for curbing the effects of climate change, and policy is an effective way for states to regulate this. Within this layer states that are red lack a greenhouse gas emissions target, states that are depicted in the lighter shade of green have either statutory targets *or* executive targets, and states in the darker shade of green have statutory targets *and* executive targets. Statutory targets are requirements passed through law that bind these states to their emissions reduction targets[18]. Executive targets are a legally binding executive action (i.e. governor's executive order) that commits the state to these actions. Thus, states with both of

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[15] "U.S. State Greenhouse Gas Emissions Targets." 2021. *Center for Climate and Energy Solutions*. March 29, 2021. https://www.c2es.org/document/greenhouse-gas-emissions-targets/.

[16] "States at Risk: Report Card." States At Risk: Report Card | States at Risk, May 22, 2019. https://reportcard.statesatrisk.org/report-card/.

[17] "U.S. State Greenhouse Gas Emissions Targets." 2021. *Center for Climate and Energy Solutions*. March 29, 2021. https://www.c2es.org/document/greenhouse-gas-emissions-targets/.

[18]" Greenhouse Gas Emissions Reduction Targets and Market-Based Policies." n.d. Accessed April 26, 2022.https://www.ncsl.org/research/energy/greenhouse-gas-emissions-reduction-targets-and-market-based-policies.aspx.

these targets enacted reflect stringent, climate friendly action. A screenshot of this layer is depicted below:

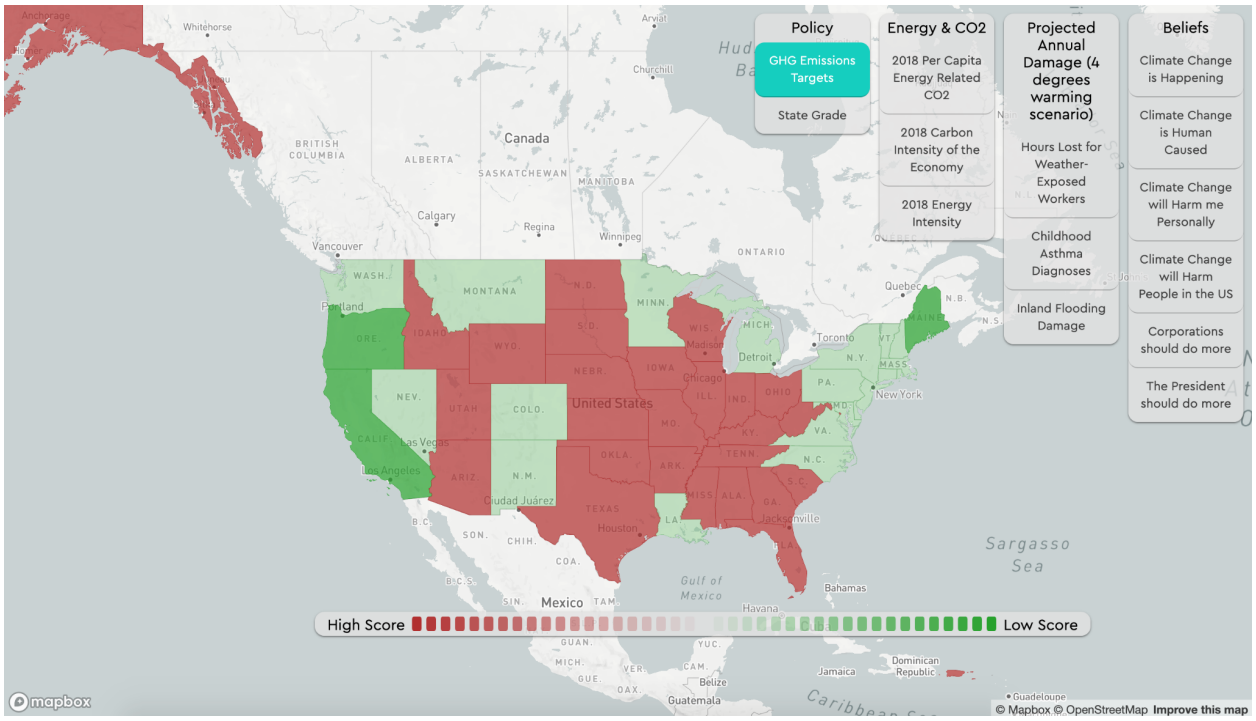

Figure 7: Greenhouse Gas Emissions Targets
(Source*:* "U.S. State Greenhouse Gas Emissions Targets." 2021. *Center for Climate and Energy Solutions*. March 29, 2021. https://www.c2es.org/document/greenhouse-gas-emissions-targets/.)

State Grade on Preparedness Scorecard

This layer uses information from a previous study that conducted research on increased climate risks threatening states and their corresponding level of preparedness[19]. The study considered five climatic threats: extreme heat, drought, wildfire, inland flooding and coastal flooding. It then assigned a grade to each state, A-F, based on their level of preparedness to these risks. Level of preparedness was judged on four core categories: taking action to reduce current risks, raising awareness of risks, planning for future risks, and implementing actions to reduce future risks. As climate change leads to more intense weather events it is critical for states to currently take steps in preparation for this[20]. Thus, this layer provides the user with key information on the level of preparedness their state has achieved, and can help inspire action where potential

[19] "States at Risk: Report Card." States At Risk: Report Card | States at Risk, May 22, 2019. https://reportcard.statesatrisk.org/report-card/.

[20] "States at Risk: Report Card."

resiliency is lacking. States with a high grade on the scorecard are depicted in green, while states with a low grade are depicted in red. A screenshot of this layer is depicted below:

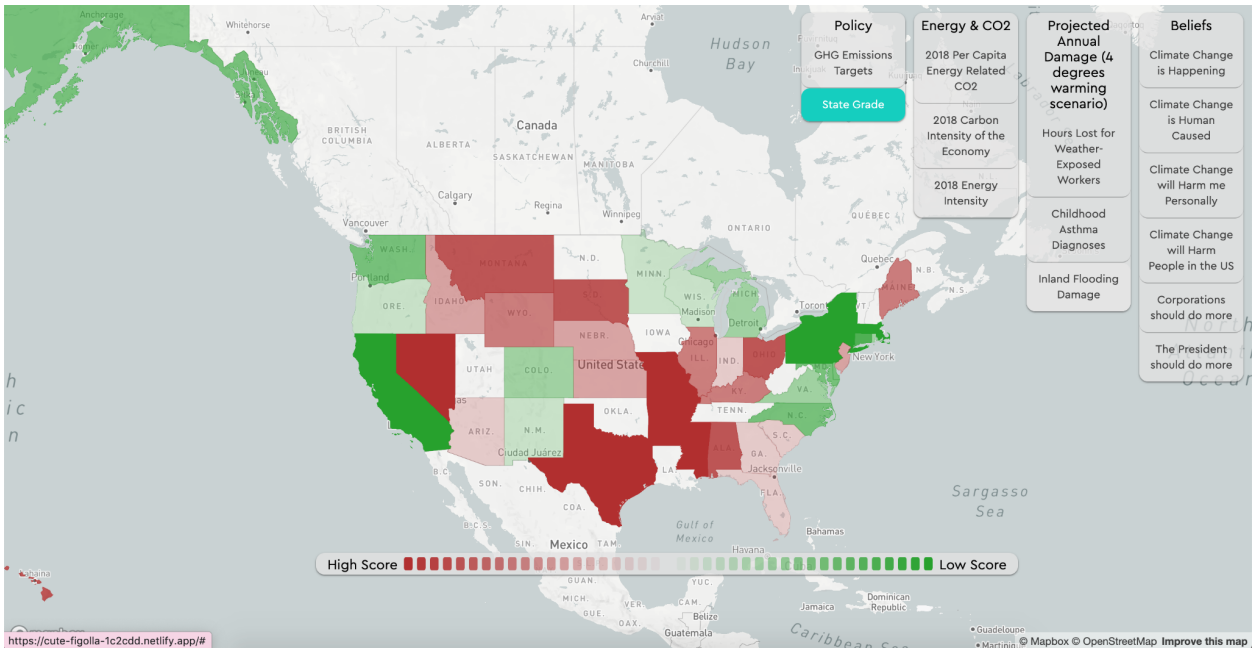

Figure 8: State Grade on Preparedness Scorecard
(Source: "States at Risk: Report Card." States At Risk: Report Card | States at Risk, May 22, 2019. https://reportcard.statesatrisk.org/report-card/.)

Energy & CO2 Layers

The third category of data we included was emissions. Anthropogenic greenhouse gas emissions are higher than ever and continue to contribute to growing concentrations of carbon dioxide, methane, and nitrous oxide in the atmosphere. As reported by the IPCC, these emissions are *extremely likely* to be the driving force of the observed warming climate since the mid-twentieth century[21]; thus, presenting data on state level emissions provides key insights into the biggest contributors to climate change in the United States. Furthermore, this category facilitates the understanding of concrete environmental realities in the United States. It allows for interesting conclusions to be drawn on where citizen perceptions and policies align or diverge with climate realities. The three datasets included in this category are:

- Per capita energy related CO2 emissions
- Carbon intensity of the economy
- Energy Intensity by State[22]

[21] IPCC, 2014: Climate, 4.

[22] "State Carbon Dioxide Emissions Data - U.S. Energy Information Administration (EIA)." State Carbon

Each of these will be explained in greater detail in the following sections.

Per Capita CO2 emissions

This map layer shows the carbon intensity of each state, measured in metric tons of energy-related CO2 per capita. Since states with a higher population are more likely to have higher emissions due to the larger amount of people and economic activity, measuring CO2 emissions per capita is a way to control for this across states[23]. Per capita measurements are achieved by dividing the total emissions for a state by that state's population. States with a low measure of per capita are depicted in green, since in this instance low emissions represents a positive outcome. States with a high measure of emissions are depicted in red. Below is a screenshot of per capita CO2 emissions in the United States:

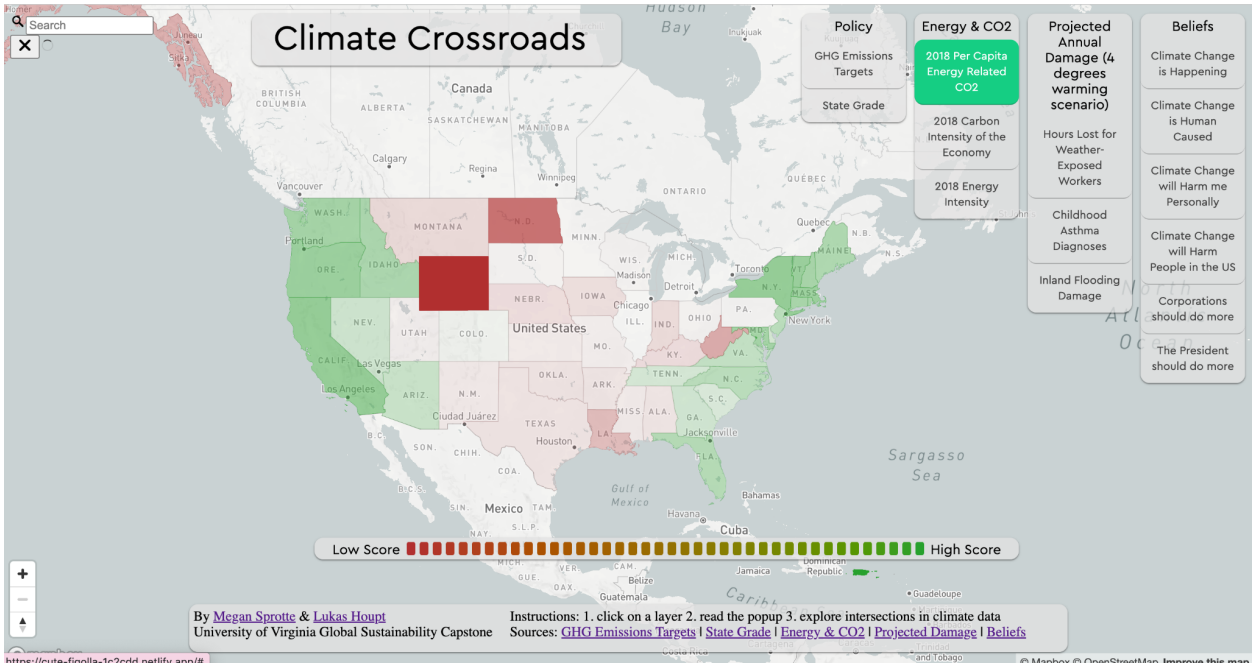

Figure 9: Per Capita Energy Related CO2 Emissions
(Source:"State Carbon Dioxide Emissions Data - U.S. Energy Information Administration (EIA)." State Carbon Dioxide Emissions Data - U.S. Energy Information Administration (EIA). Accessed February 3, 2022. https://www.eia.gov/environment/emissions/state/.)

Dioxide Emissions Data - U.S. Energy Information Administration (EIA). Accessed February 3, 2022. https://www.eia.gov/environment/emissions/state/.

[23] Baumert, Kevin A., Timothy Herzog, and Jonathan Pershing. 2005. *Navigating the Numbers: Greenhouse Gas Data and International Climate Policy*. Washington, D.C: World Resources Institute.

Carbon Intensity of the Economy

The carbon intensity of an economy is the level of greenhouse gas emissions per unit of economic output[24]. This measure helps to indicate two other major emissions descriptors in a states economy: energy intensity, which reflects an state's energy efficiency and overall economic structure, and the fuel mix of the economy in that state[25]. Thus, we found this measure to be a useful indicator of which states' economies are at the forefront in terms of climate friendliness. States with a low carbon intensity of the economy are depicted in green, since in this instance 'low' represents a positive outcome. States with a high measure of carbon intensity are depicted in red. This layer specifically shows the intensity of the economy measured in metric tons of energy-related CO2 per million dollars of GDP, and is depicted below:

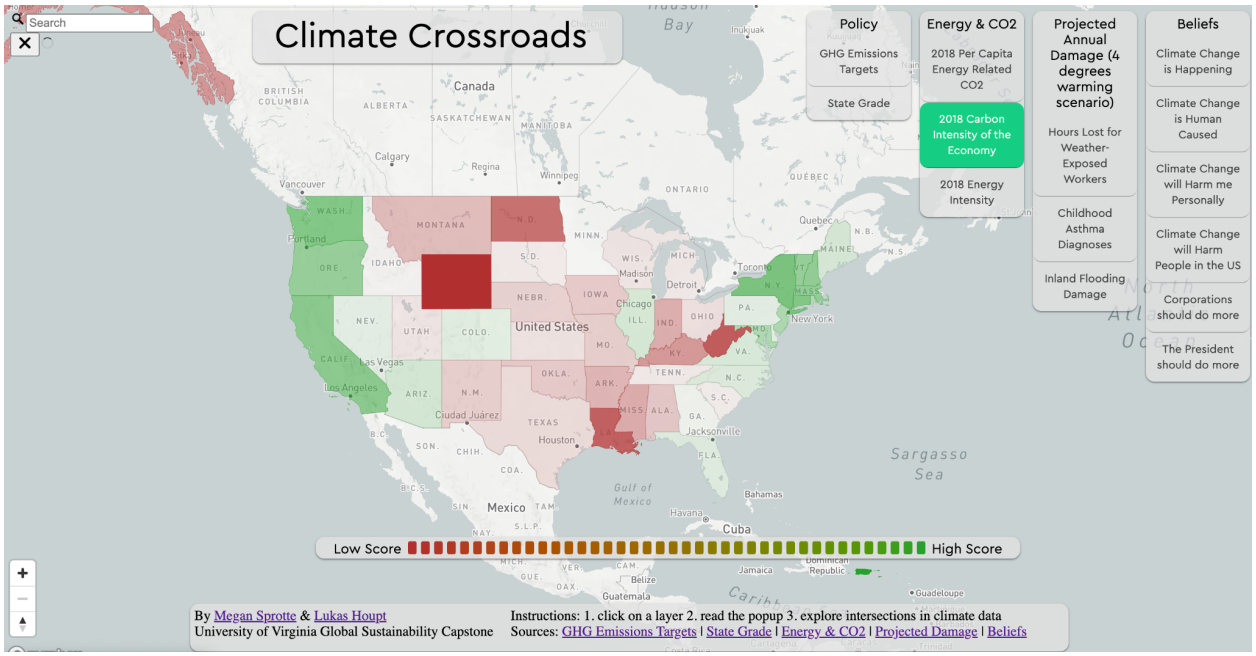

Figure 10: Carbon Intensity of the Economy
(Source: "State Carbon Dioxide Emissions Data - U.S. Energy Information Administration (EIA)." State Carbon Dioxide Emissions Data - U.S. Energy Information Administration (EIA). Accessed February 3, 2022. https://www.eia.gov/environment/emissions/state/.)

[24] Baumert, *Navigating,* 25.

[25] Baumert, *Navigating,* 26.

Energy Intensity by State

This map shows the energy intensity of each state, measured in thousand Btu per dollar of 2012 GDP. Energy intensity is measured by the quantity of energy required per unit output[26]. This measurement is useful because it provides insight into the energy efficiency of each state's energy production because declines in energy intensity occur when energy efficiency increases[27]. States with a low measure of energy intensity are depicted in green, since in this instance 'low' represents a positive outcome. States with a high measure of energy intensity are depicted in red. Below is the screenshot for energy intensity by state:

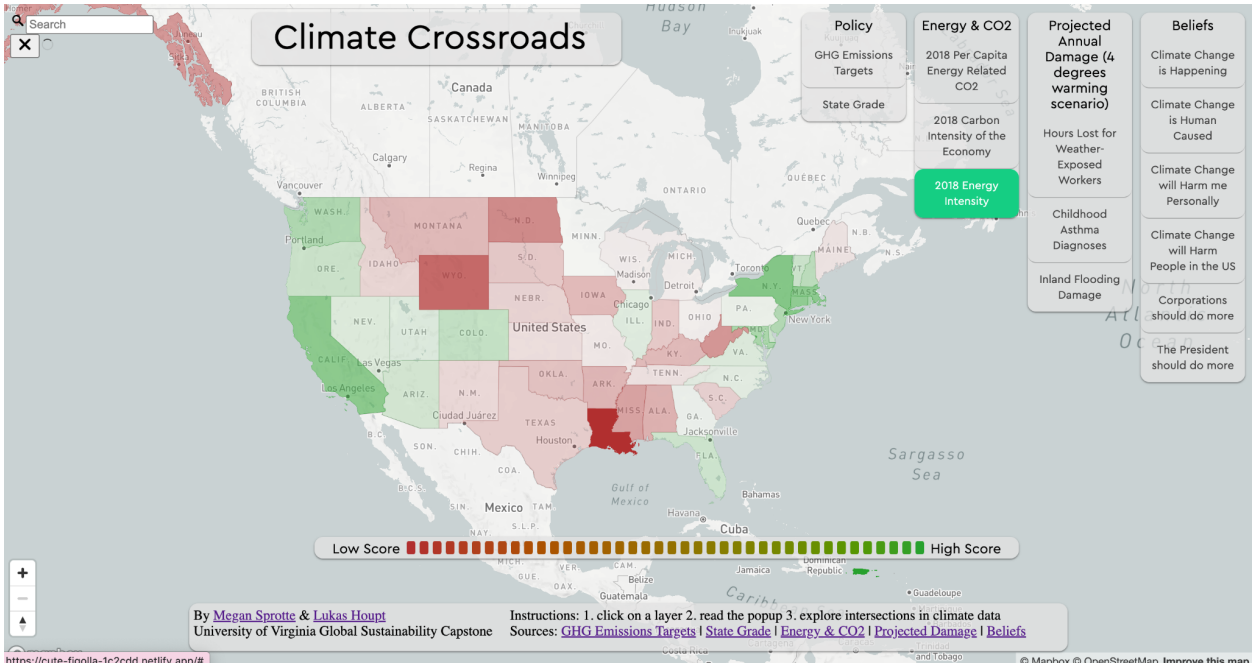

Figure 11: Energy Intensity by State
(Source*:* "State Carbon Dioxide Emissions Data - U.S. Energy Information Administration (EIA)." State Carbon Dioxide Emissions Data - U.S. Energy Information Administration (EIA). Accessed February 3, 2022. https://www.eia.gov/environment/emissions/state/.)

Damages Layers

The final category included was projected damages. These data sets were included to display aspects of social vulnerability that are expected to result from climate change in the coming years under a 4 degree warming scenario. Providing this information will help users

[26] "Energy Efficiency vs. Energy Intensity." n.d. Energy.Gov. Accessed May 3, 2022. https://www.energy.gov/eere/analysis/energy-efficiency-vs-energy-intensity.

[27] "Energy Efficiency vs. Energy Intensity."

draw necessary conclusions on which populations will be the most vulnerable given the estimated future effects of climate change. These data sets provide a needed social context on the climate crisis and can be used in concurrence with the data presented above to draw deeper conclusions on the intersection of social and environmental problems. The data for this category was retrieved from the United States Environmental Protection Agency's report on Climate Change and Social Vulnerability[28]. The included data sets are:

- Projected Labor Hours Lost for Weather Exposed Workers
- Projected Changes in Childhood Asthma Diagnoses from Air Quality depletion
- Projected Annual Inland Flooding Damages

The data retrieved from this study is missing the spatial attributes for certain states, namely Alabama, Alaska, Arizona, Arkansas, California, Colorado and Connecticut. Nevertheless, we still found this to be interesting data and a prime example of the intersection of social vulnerability and climate change. Thus, the data we could download was included. It's common for datasets to be incomplete or include null data, and our project is no exception.

Projected Annual Labor Hours Lost

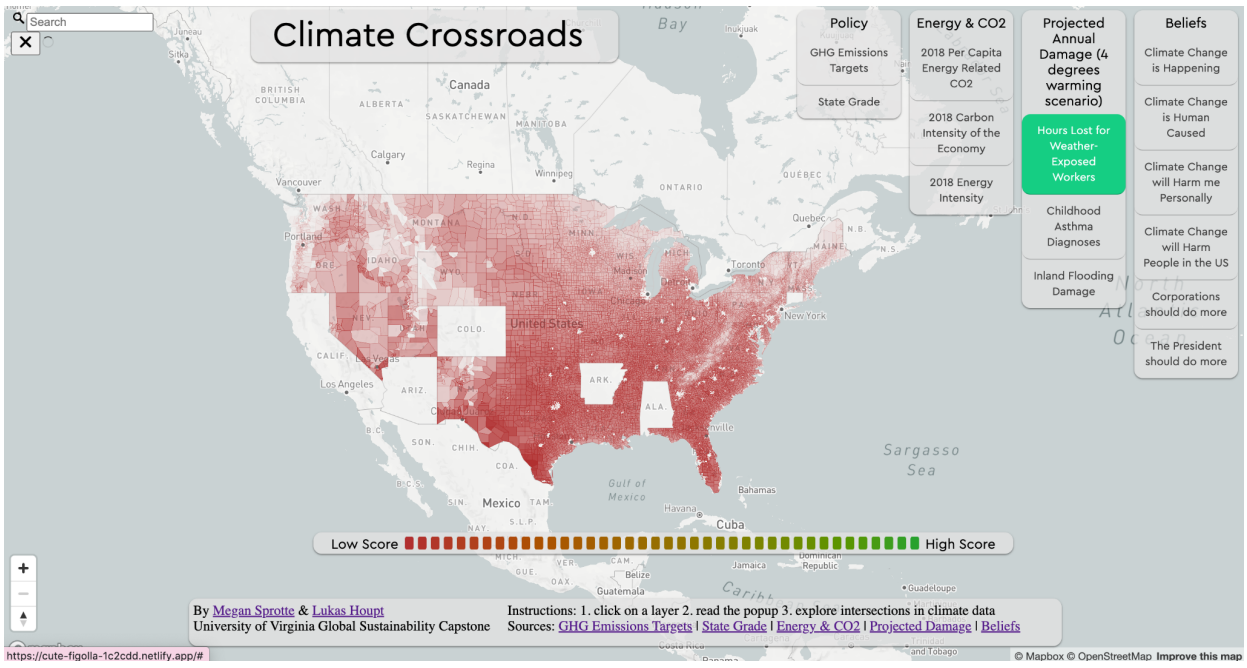

Figure 12: Projected Annual Labor Hours Lost
(Source: "United States Environmental Protection Agency. 2021. "Climate Change and Social Vulnerability in the United States: A Focus on Six Impacts," September, 1-101.")

[28] United States Environmental Protection Agency. 2021. "Climate Change and Social Vulnerability in the United States: A Focus on Six Impacts," September, 1-101.

This layer depicts the projected labor hours lost across states under a four degree warming scenario. Among the primary effects of climate change are increases in temperature across the globe. As a result of this, there will be significant disruptions to the labor sector, especially where people work outdoors or in indoor environments without air conditioning[29]. Certain sectors will have to spend less time working on extreme temperature days which threatens their livelihood and can potentially have statewide economic impacts. This study focused primarily on the following weather exposed industries: agriculture, forestry, fishing and hunting; mining; construction; manufacturing; transportation and utilities[30]. This data was important to include because certain sectors and certain parts of the country will experience this loss of labor on a much larger scale than others, potentially contributing a great deal to social inequality in the United States. States with a low number of labor hours lost are depicted in green, since in this instance 'low' represents a positive outcome. States with a high number of hours lost are depicted in red. A screenshot of this layer is included on the page above.

Projected Changes in Childhood Asthma Diagnoses

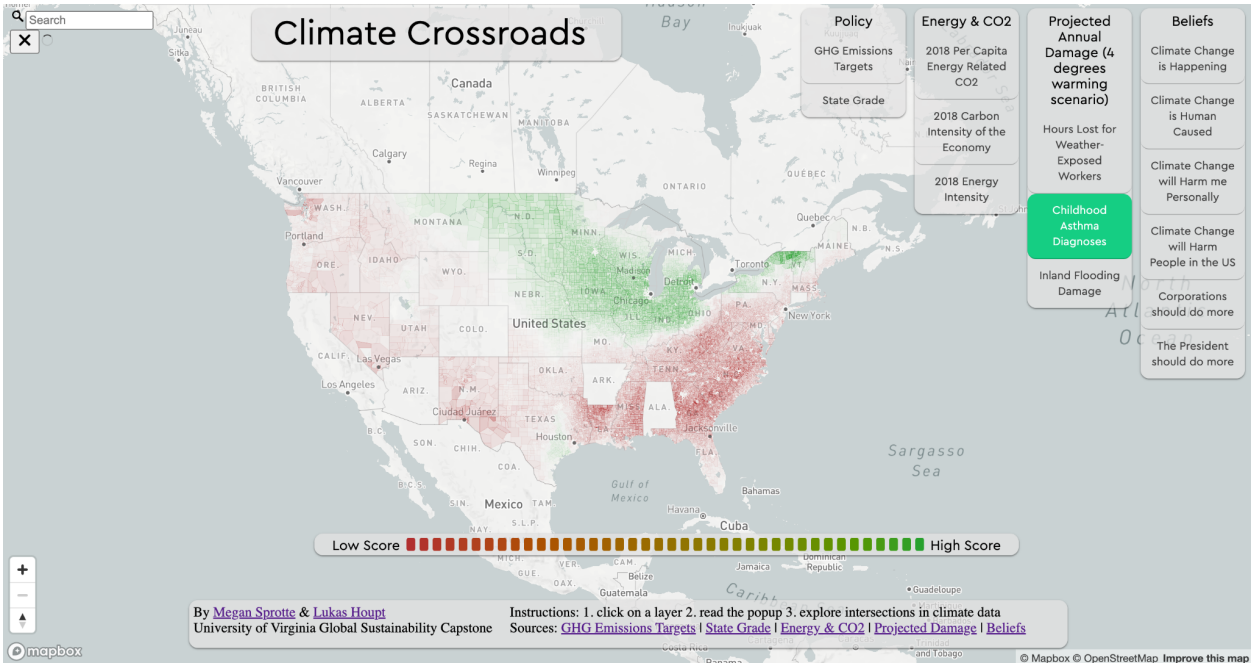

Figure 13: Projected Increase in Childhood Asthma Diagnoses
(Source: "United States Environmental Protection Agency. 2021. "Climate Change and Social Vulnerability in the United States: A Focus on Six Impacts," September, 1-101.")

[29] United States , "Climate Change", 37.

[30] United States , "Climate Change", 37.

This layer depicts the projected increase in childhood asthma diagnoses under a four degree warming scenario. Climate change and related emissions will alter the chemical composition of our atmosphere and the physical interaction people have with it. These changes are likely to have significant respiratory and cardiovascular health effects on the population[31]. This layer provides important information on which childhood populations will be most affected by and the most vulnerable to this occurrence. States with minimal to no increases in childhood asthma are depicted in green. States with a high projected change in diagnoses are depicted in red. A screenshot of this layer is included on the page above.

Projected Annual Inland Flooding Damages

This layer depicts the projected annual inland flooding damages under a four degree warming scenario. While sea level rise and coastal flooding are commonly known effects of climate change, increases in inland flooding are discussed much less. Excessive rainfall and heavier downpours will overflow water sheds, subsequently threatening human health and safety, and

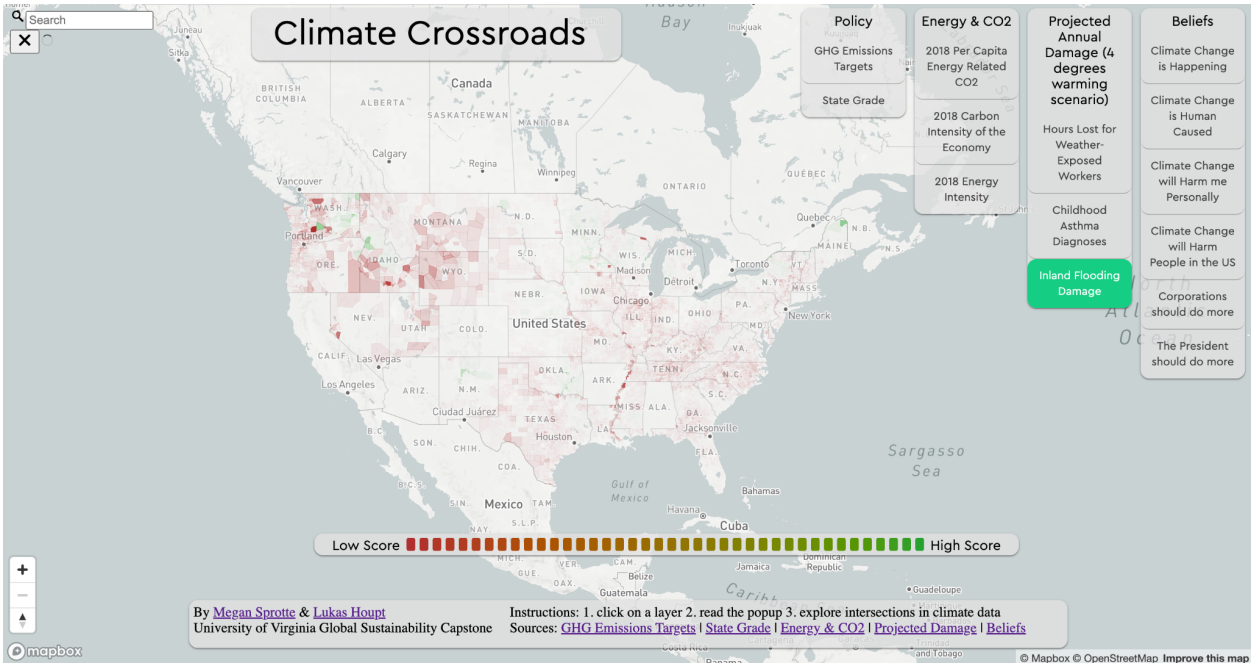

Figure 14: Projected Increase in Inland Flooding
(Source*:* "United States Environmental Protection Agency. 2021. "Climate Change and Social Vulnerability in the United States: A Focus on Six Impacts," September, 1-101.")

[31] United States , "Climate Change", 20.

damaging property and natural resources[32]. This layer specifically looks at property damage and loss resulting from the increase in inland flooding, and reveals the most vulnerable populations. Areas with a low amount of projected damages are depicted in green, since in this instance 'low' represents a positive outcome. Areas with a high amount of projected flooding damages are depicted in red. A screenshot of the layer is included on the page above.

Conclusions & Future Research

The categories above and their corresponding data sets ensure that we have adopted an interdisciplinary approach in the creation of our map. Each of the categories present data that has the potential to highlight interesting correlations and divergences on the state level. The conclusions drawn from this map will facilitate the user in better understanding the relationships among environmental realities, citizen perceptions, state policies and social vulnerabilities. Some of the most interesting conclusions are discussed below.

Within the perceptions and beliefs category one interesting conclusion that arose is that the percentage of people that think climate change is happening from human activities is lower in every state than the percentage of people that believe climate change is happening overall. This occurrence happens regardless of political voting tendencies for the state. The data source did not include alternative reasons for why people believe climate change is happening if not from human reasons. In light of these discrepancies this would be an interesting place for future research on climate change beliefs in the United States.

Another interesting conclusion that arose from this category is that there is a large discrepancy between the percentage of people that believe climate change will harm them personally versus the percentage of people that believe it will harm other people in the United States, with much higher percentages being recorded on the latter. This is interesting because while the perception of climate risks usually divides along political lines[33], this discrepancy exists in both blue and red states. One potential reason for this discrepancy is because the dangers of climate change are often discussed abstractly as a future issue based on predictions, probabilities and advanced scientific models which has led to an underestimation of risk and

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[32] United States , "Climate Change", 68.

[33] Schwaller, Nora Louise, Sophie Kelmenson, Todd K. BenDor, and Danielle Spurlock. 2020. "From Abstract Futures to Concrete Experiences: How Does Political Ideology Interact with Threat Perception to Affect Climate Adaptation Decisions?" *Environmental Science & Policy* 112 (October): 440–52. https://doi.org/10.1016/j.envsci.2020.07.001.

public concern[34]. A potential solution to this is to focus on specific, local examples of climate threats rather than abstract, global trends[35]; however, more research on threat perception and the existence of this divergence in the United States is needed.

A final conclusion drawn from this category is that again, regardless of political voting patterns and general feelings towards government intervention, both red and blue states feel that corporations should do more to prevent climate change in comparison to the President. Further research is needed on whether this discrepancy arises because of American citizen's doubt that the government has the capacity to make concrete impacts, because they feel the government is already doing enough, because they feel that corporations are primarily responsible for climate change, or for a different reason entirely.

Within the policy layers we found it interesting that certain west coast states such as California received high grades on the state preparedness scorecard, despite the high number of intense climate driven events they experience. As stated in the scorecard methodology this could be due to the fact that their preparedness (i.e. taking action to reduce current risks, raising awareness of risks, planning for future risks, and implementing actions to reduce future risks)[36] in response to overall climate threat was high in comparison to other states. This potential explanation is strengthened by the fact that California is one of three states that has enacted both statutory and executive targets, as displayed in the greenhouse gas emissions targets layer.

When looking across categories there are a number of interesting observations that can be made. For example, Louisiana has enacted executive emissions targets, however, they had the highest 2018 energy intensity of any state in the US. It would be interesting to see how these emissions are dispersed across sectors. Furthermore, it would be useful to see how energy intensity has increased, decreased or remained the same since the recorded 2018 levels.

In addition to suggested investigations into the discrepancies we discovered listed above, it would also support our map to include a more comprehensive assortment of data layers. For example, with all layers toggled on, the overall top performers appear to be California and Colorado due to their progressive belief sets, low projected damage, energy &

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[34] Schwaller et. al, "From Abstract" 440.

[35] Schwaller et. al, "From Abstract" 450.

[36] "States at Risk: Report Card." States At Risk: Report Card | States at Risk, May 22, 2019. https://reportcard.statesatrisk.org/report-card/.

CO2, and state policy. However, these states in fact appear in the news for climate events more frequently than so many other states, especially in the categories of extreme drought and wildfires. A number of projected damage sources should be added in a V2.0 of our map including drought, wildfire, hurricane, coastal flooding, sea level rise, storms, tornadoes, etc., such that no discrepancies exist between real-life projected damage and what projected damage we present on this map.

As this tool is meant for public outreach and education, we would like to survey users for their input on features we would include in a future version. Whether this is more comprehensive data coverage, more granular data (cities, counties, localities), global data, better popups, descriptions, etc., we feel these priorities should be specified by users via surveys. We see strong potential for a tool like this to answer questions and illuminate interdisciplinary intersections across climate change and serve as a useful tool for the general public, and we'd love to see this project earn grant funding and pass down to future generations of GSVS Environments and Sustainability students.

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