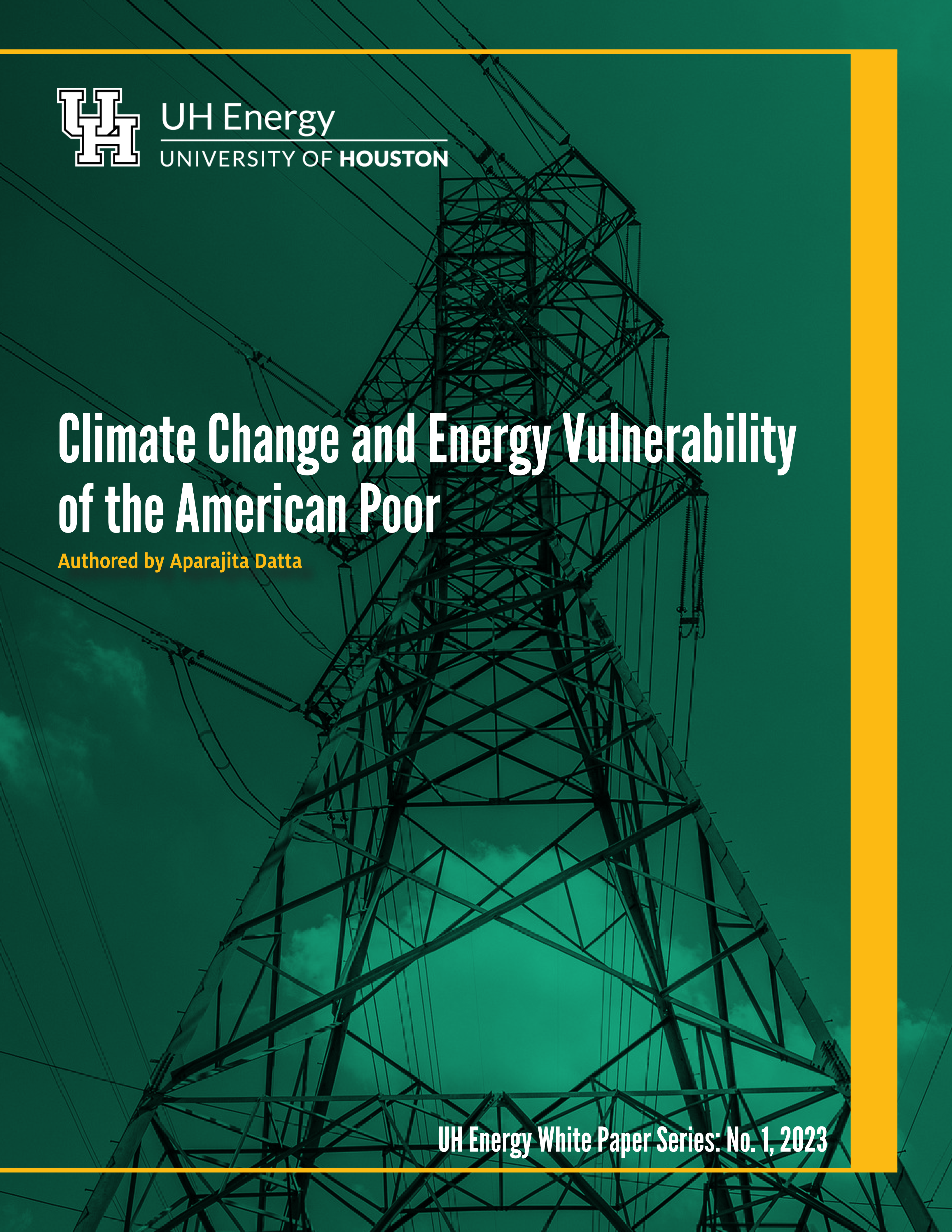

UH Energy
UNIVERSITY OF HOUSTON

Climate Change and Energy Vulnerability of the American Poor

Authored by Aparajita Datta

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About the Author

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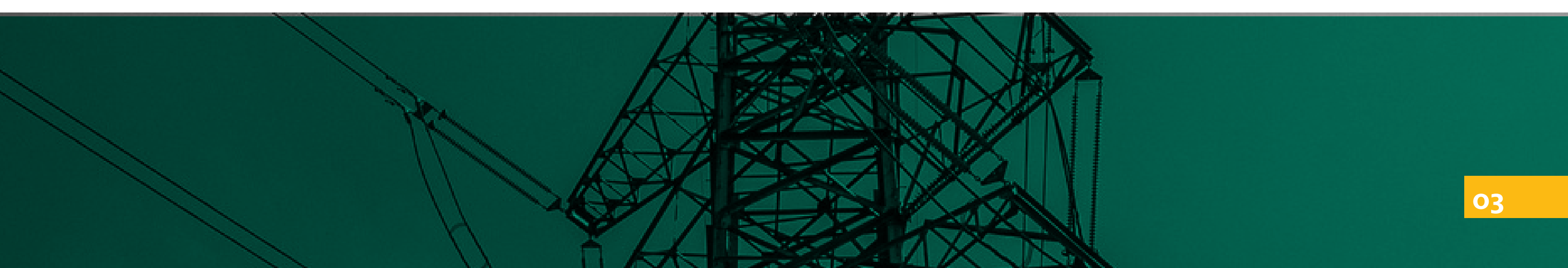
EXECUTIVE SUMMARY

Income inequality and climate change are two of the defining challenges of a transformative era. One of the most obvious ways in which they intersect is that many of the nations that can least afford to deal with it, are most likely to suffer the catastrophic impact of rising sea levels, hotter temperatures, and more frequent storms. The complex interactions between income inequality and climate change will hit closer to home as well. The effects will continue to disproportionately impact the most vulnerable populations, especially low-income communities. Despite strong empirical and systematic evidence highlighting the intertwined nature of income inequality and the impacts of climate change, it has been difficult to develop, adopt, and sustain holistic policies that simultaneously address both challenges.

In the absence of a broader federal framework over the last several years, state and local policies related to emissions and greenhouse gas reductions, energy efficiency for buildings and appliances, alternative transportation, grid decarbonization, carbon pricing, and workforce development for the energy transition have led to crucial policy learnings. These lessons, including unintended consequences, informed the passage of the Infrastructure Investment and Jobs Act of 2021 and the Inflation Reduction Act of 2022. As the country begins to implement policies related to these new federal laws, the costs and distributional impacts of these state policies, including their potential to exacerbate income inequality, require further exploration.

To determine how these policies have impacted different groups, we created a Climate Policy Index, using panel data from all 50 U.S. states between 2010 and 2019. Our analyses indicate that:

- Stronger and more expansive climate policies result in a higher median energy burden, represented by the percentage of household income required to pay the household's energy bills. This finding is consistent across low-, medium-, and high-income communities.
- Low-income communities bear the most substantial impact as the scope and strength of climate policies increase, suggesting that climate policies across states indeed have a regressive distributional impact. This finding also holds when the top seven energy-producing states, fossil fuels and renewable energy, are excluded from the analysis.
- In fact, the impact of climate policies on the energy burden for low-income communities is four times higher than for the median-income group, six times higher than for the middle-income, and eight times higher than for the high income.
- The energy burden is largest in the states in which a greater share of the population lives below the federal poverty level. These costs regressively burden the poorest residents, pushing many to spend almost a quarter of their income on electricity.
- The energy burden on the poor is higher in states with both Democratic and Republican governors, as compared to states with an Independent governor. The impact was greatest in states with a Democratic governor. However, the effect cannot be interpreted as the result of political parties alone. A combination of voting behavior, voter partisanship, ideology, energy consumption, utility rates and bills, geography, and when and how homes are constructed are likely at play. While the study controls for aggregate state-level characteristics like the average price of electricity and natural gas, and heating and cooking degree days, voter-level data has not been included at this stage of the analysis.



INTRODUCTION

Through the past decade of energy abundance in the U.S., Americans have had adequate energy access to support an array of economic activities and to ensure that their homes are comfortable and safe. However, energy abundance and access have not translated to energy affordability. Between 2012 and 2022, the price of residential electricity in the U.S. increased by 27%[1]. The low-income have been adversely impacted by the increasing price of electricity as federal means-tested programs for utility bill assistance, Low Income Home Energy Assistance Program (LIHEAP), and energy efficiency, the Weatherization Assistance Program (WAP), have suffered from a lack of funding, coordination problems between federal and state governments, and high administrative burdens[2]. With increasing costs and insufficient policy assistance, low-income communities spend a greater share of their income on electricity than people with higher incomes. This share, also known as the energy burden, is typically between 3% and 5% for all U.S. households. However, that rises to between 15% and 18% for most low-income households. In 2019, the poorest of the low-income spent more than 23% of their income on electricity[3]. Specifically, the energy burden remains particularly high for those living in the southern states, rural communities, and communities of color. Concomitantly, previous works have suggested that climate policy instruments like carbon pricing, emissions controls, and energy subsidies are ecologically effective and economically efficient[4]. However, they can have direct and indirect regressive effects on low-income residents by increasing the cost of electricity and an economy-wide increase in the cost of all goods and services.

Therefore, three questions are central to solving the challenges posed by income inequality and the impacts of climate change.

1. What is the impact of climate policies on the energy burden across all U.S. states?
2. Are there disparities in how the policies impact different income groups?
3. Is the distributional impact of climate policies progressive or regressive?

This study draws on panel data from all U.S. states[1] to evaluate the impact of state climate policies on the median-, low-, middle-, and high-income energy burdens between 2010-2019. For this study, we created a Climate Policy Index, a dynamic measure of policy strength and scope in six climate-oriented domains i.e., state emissions targets, state climate action plans, state and regional carbon pricing initiatives, state electricity sector standards, state energy efficiency standards, and state transportation and fuel standards, using factor analysis. Additionally, measures of real personal income growth across all states, the share of the population living below the federal poverty level, state and federal executive and legislative control, and economic indicators such as the price of electricity and natural gas are used to examine the distributional impacts of state climate policies.

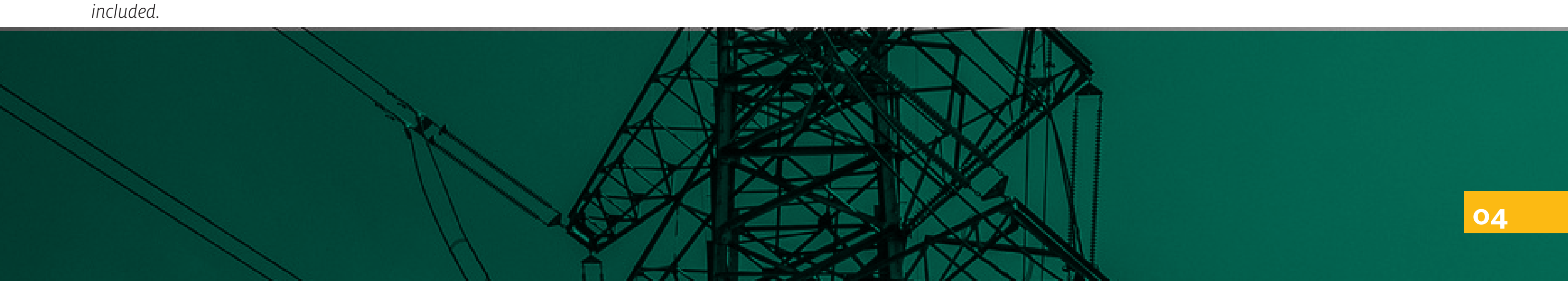
ABUNDANT BUT UNAFFORDABLE: ENERGY BURDEN, VULNERABILITY AND POVERTY

In 2019, the U.S. became a net energy exporter for the first time since 1952[5]. Growth in domestic crude oil and natural gas production propelled energy independence and strengthened national energy security. The abundance of natural gas has also meant that the U.S. was able to produce affordable electricity and provide reliable access while reducing carbon emissions from the electricity sector by 30% between 2005 and 2019. Over the same time, the economy grew by 25%, indicating that the successful decoupling of emissions and GDP had begun[7].

Even though energy is available and accessible, that does not equate to energy affordability. Energy burden, or the share of income spent on electricity, is a key metric for policymakers when developing and advancing energy programs. Despite energy abundance, energy burdens in the U.S. are persistently increasing and are a contributing source to inequality. The price of residential electricity in the U.S. increased by 15% between 2010 and 2019, while nominal income grew by about 3% over the same time[6]. The U.S. Department of Energy considers a household spending more than 6% of its annual income on electricity as facing a high energy burden[7]. In 2018, the agency found that the nationwide energy burden faced by low-income households is three times higher than those of other households. Regionally, the disparities are starker, with the five states with the highest energy burden all in the south – Mississippi, South Carolina, Alabama, Georgia, and Arkansas[7].

Many factors contribute to the energy burden, ranging from average electricity consumption in each state, the age and overall energy efficiency of the housing stock, and weather; but the most significant factor is the price of electricity, which is dependent on the energy mix used in power generation, as well as the policy and regulatory environment. While the impact may not be apparent on an everyday basis, the long-term consequences of the resulting inequality are severe. A high energy burden not only impacts how much a household pays for the electricity it consumes but can have spillover effects, which can jeopardize the ability to pay for electricity and increase energy vulnerability, but also redirect household spending away from food, education, healthcare, or other necessities. In 2020, as families spent more time at home due to the pandemic and amid an unprecedented economic downturn, many struggled to maintain their energy access. Two months into the pandemic-induced lockdowns, a national survey found that 3% of households had been unable to pay their electricity bill in April 2020, 9% had received an electricity

[1] *A Climate Policy Index was constructed for the District of Columbia (D.C.). Regression models were evaluated with and without Washington D. C. The results reported in the paper do not include Washington D.C.; however, substantive results did not change when included.*



shutoff notice due to their inability to pay their bills, and 4% had their electric service disconnected[8].

Federal means-tested programs for energy assistance and energy efficiency, LIHEAP and WAP, were created to help low-income people pay their electricity bills and make their homes more energy efficient, lowering energy use and, thus, their utility bills. The programs have mostly enjoyed bipartisan support and have helped many households, including vulnerable populations such as the elderly, disabled, and those with fixed incomes to pay for the electricity they consume and live with energy access and security.

Studies on infants and children in low-income communities have revealed that access to LIHEAP and WAP funding reduced the chances of mortality and hospital visits, and improved health outcomes[9]. Despite being crucial for low-income residents, both programs have suffered from a lack of funding, policy non-coordination, and a lack of understanding of the social and economic benefits of energy conservation, energy education, and flexible utility billing policies[10,11]. Typically, funding for both programs has been only about 0.5% of total government spending on means-tested welfare programs each year[12]. The combination of rising income inequality, increasing electricity prices, and inadequate government funding has resulted in persistently high energy burdens, especially for the low-income.

THE CONFLICT BETWEEN ENERGY POLICY AND CLIMATE POLICY

Historically, GDP and energy consumption have been tightly coupled – richer nations use more energy – and as a result, the emissions associated with energy consumption have been higher for developed economies. The decoupling of GDP and emissions in the U.S. was viewed as a benchmark for developed countries, but more than a decade later the U.S. continues to be one of the highest global emitters and has yet to adopt and enact a holistic national climate policy. With growing concerns about the increasing concentrations of carbon dioxide (CO_2) and other greenhouse gases in the atmosphere and the impacts of climate change, some states have stepped up to fill the vacuum of federal climate leadership[13]. In a short timeframe, many of the enacted state-level policies have demonstrated promising results, which has prompted Congressional attention to the lessons learned from these state policies[14]. While climate policies, like carbon pricing, emissions controls, and energy subsidies, are ecologically and economically efficient[15,16], their direct and indirect effects often lead to a conflict with energy equity. While a price on emissions is an effective tool to advance climate change mitigation across all sectors of the economy and the energy value chain, it may result in short-run changes to prices that can disproportionately burden vulnerable communities[17,18].

Energy equity is central to mitigation policies that simultaneously address issues of energy and climate change. The conflict between climate and energy policies exacerbates the distributional impact of increasing energy burden for the low-income. While fewer low-income households are eligible to participate in most energy efficiency, decoupling, and renewable energy programs, the programs are typically financed by increasing the price of electricity for all consumers[19]. These outcomes are most pronounced and regressive for low-income communities[20,21,22].

DATA AND MEASUREMENT

CLIMATE POLICY INDEX

To investigate the three questions outlined above, panel data from 2010-2019 on all 50 U.S. states were utilized to test the hypotheses. Data from the Center for Climate and Energy Solutions was used to construct the measure of policy scope and strength, the Climate Policy Index, as detailed in this work. The principal characteristics leading to the selection of the six policy domains were 1) the direct and simultaneous impact of the policy on greenhouse gas emissions reduction and the electricity value chain- production, distribution, and consumption, and 2) the availability of yearly policy data condensed to a common qualitative scale across all states. The qualitative scale, described in Table 1, was converted to a normalized ordinal scale such that carbon pricing, climate action plan, transportation sector policies, and greenhouse gas target were scaled from 0-3 (based on 4 categories of variations in policies), energy sector portfolio standards and energy efficiency policies were scaled from 0-6 (based on 7 categories of variations in policies). Table 1 includes details on each category and the scales, with additional details comparing the scope and adoption of policies included in Appendix A.

The six policy domains were factor analyzed to create the Climate Policy Index. Factor analysis is a statistical method that identifies the common variance among a set of observed variables and uses it to create an index or factor with a linear equation of the weighted contribution of each variable. Hence, the variables that are observed to vary together are grouped to identify the underlying "factor" that causes them to be related. The output of a factor analysis provides a mathematical combination of the variables where a portion of each variable contributes to an overall factor score. The share of contribution to the composite index depends on the degree of commonality with all the variables.

The contribution of a variable to a factor is its factor loading, which can range from -1 to +1, such that the larger the absolute size, the greater the variance of the variable explained by the factor. If the results indicate that there is one underlying factor between the variables, a single factor score can be used to describe the entire dataset.

Here, the factor analysis yielded a one-factor solution with an eigenvalue greater than 1 (the eigenvalue for the second factor was 0.48) and explained 91% of the

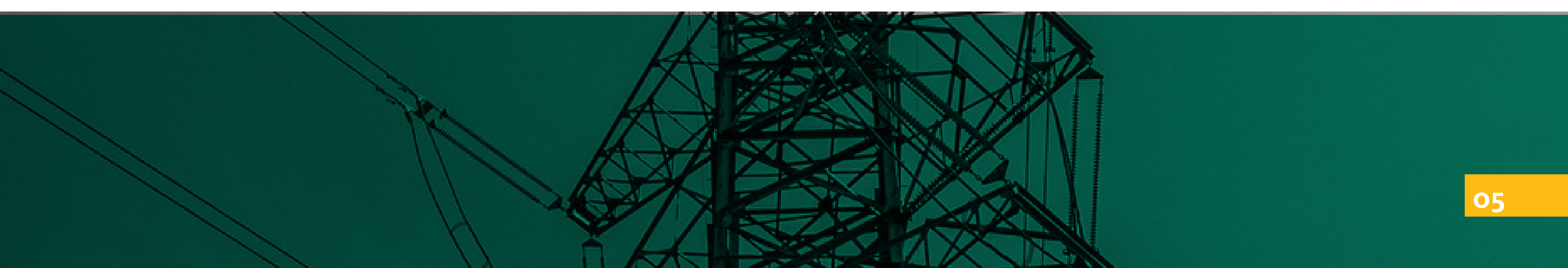


TABLE 1. POLICY DOMAINS AND SCALES USED TO MEASURE THE CLIMATE POLICY INDEX

Policy Domain	Scale
Carbon Pricing	0 - No carbon price
	1 - State cap & trade
	2 - Partner State in Regional Greenhouse Gas Initiative (RGGI)
	3 - RGGI + State Cap &Trade
Energy Sector Portfolio Standards	0 - No portfolio standard
	1 - Clean Energy Goal
	2 - Renewable Energy Goal
	3 - Alternative Energy Portfolio Standard (APS)
	4 - Clean Energy Portfolio Standard (CPS)
	5 - Renewable Portfolio Standard (RPS)
	6 - APS + CPS + RPS
Climate Action Plan	0- No climate action plan
	1 - Developing
	2 - Updating
	3 - Released and Enforced
Energy Efficiency Policies	0 - No energy efficiency policy
	1 - Loss revenue adjustment for gas utilities
	2 - Loss revenue adjustment for electricity utilities
	3 - Loss revenue adjustment for electricity and gas utilities
	4 - Decoupling revenue from the volume of sale - gas utilities
	5 - Decoupling revenue from the volume of sale - electricity utilities
	6 - Decoupling gas and electricity utilities
Transportation Policies	0 - No fuel standards
	1 - Alternate fuel standards
	2 - Low-carbon fuel standards
	3 - Alternate and Low-carbon fuel standards
Greenhouse Gas Target	0 - No greenhouse gas target
	1 - Executive target
	2 - Statutory target
	3- Executive and Statutory target

variance. Factor loadings ranged from 0.44 to 0.73. The factor scores based on regression scoring were used as the Climate Policy Index and ranged from 0 to 3.36. All factor loadings and the Climate Policy Index for all 50 states from 2010-2019 are reported in Appendix B. Substantively, higher values for the Climate Policy Index indicate a broader scope and strength of policies.

ENERGY BURDEN

Energy burden is defined as the share of income spent on electricity. As discussed above, a household spending more than 6% of its annual income on electricity is considered to be experiencing a high energy burden. Data from the American Trends Panel of the Pew Research Center on median state income, and low-, middle-, and high-income were used to calculate the energy burden in each state and across income groups[23,24]. Low-income households are defined as having an annual income of less than two-thirds of the median, middle-income households have an annual income between two-thirds to twice the median income, and high-income households have an annual income greater than twice the median.

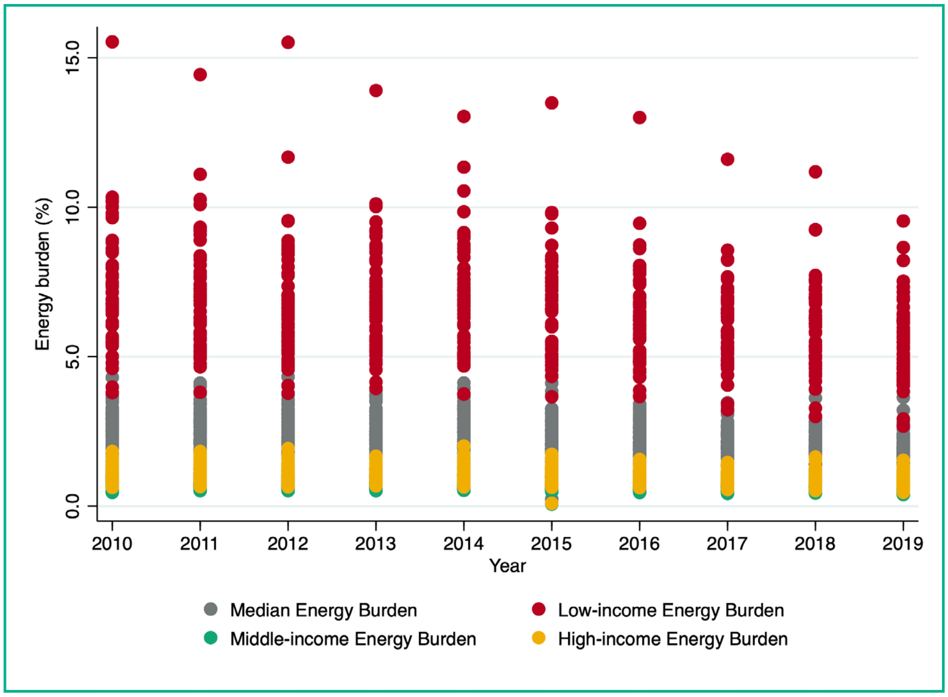


FIGURE 1. The distribution of the energy burden across income groups between 2010 and 2019.

The incomes were adjusted by household size and scaled to represent a household of three. Data from the U.S. Energy Information Administration (EIA) on the monthly average bill in each state was used to compute the average annual bill. The average annual bill was then divided by median-, low-, middle-, and high-income values to obtain the percentage of income spent on electricity or the energy burden. Figure 1 provides a comparison of the energy burden across all income levels.

Overall, the median energy burden averaged from 0.2 to 4.8 (mean = 2.4, standard deviation (s.d.) = 0.6) between 2010 and 2019. Middle-income energy burden was between 0.07 to 1.5 (mean = 0.8, s.d. = 0.2) and the high-income energy burden was between 0.1 to 2.0 (mean = 1.0, s.d. = 0.3. In contrast, the average low-income energy burden averaged between 0.5 to 15.5 (mean = 6.5, s.d. = 1.8) over the same time[2].

OTHER EXPLANATORY MEASURES

Data from the Bureau of Economic Analysis on real personal income growth rates across all U.S. states was used to account for changes to energy burden from variabilities in income. The analysis also accounted for the share of the state's population living under the federal poverty level as a percentage of the total state population, as states with a higher share of low-income households are expected to have a higher energy burden. The state's total population was also controlled to account for higher energy consumption as compared to states with lower populations.

Data from the U.S. Energy Information Administration on the average annual price of residential electricity, in cents per kWh, and natural gas, in dollars per thousand cubic feet, were used to account for the heterogeneity in the price of residential electricity across states. Data on annual energy production in each state, measured in million British thermal units (MMBtu), was used to account for states that are producing a greater share of the energy they consume locally, and therefore are likely to pay lower costs for electricity production and distribution. This measure was also introduced as a proxy for the impact of the energy sector on the state's economy, as states that produce more energy are likely to employ a larger share of their population in the sector. Any variations in energy supply and demand or shocks to energy production will impact associated jobs, thereby impacting income, and impact the price of electricity. Both factors together will impact the energy burden. Data on Heating and Cooling Degree Days from the National Oceanic and Atmospheric Administration (NOAA) across the nine Census regions were used to control for the average days requiring household heating and cooling during any given year[3].

Political and policy impact measures were included using executive and legislative control variables at the state level and by controlling for the president's party. Executive control was measured as the governor's party (Democrat, Republican, or Independent). All regression results for this measure presented in the next section are compared against a baseline of an Independent governor. Legislative control was measured as the party in control of the state Senate and House (Democrat, Republican, or split). All regression results for this measure are compared against a baseline of split control of the state legislature[4].

Lastly, all regression results in the next section compare the impact of executive control, where the baseline of a Democrat president is compared against that of a Republican president. Energy assistance from the federal government was measured through annual appropriations from the Low-Income Home Energy Assistance Program (LIHEAP) in million $.

[2] *Energy burdens across income groups do not follow a normal distribution. We have not used non-parametric methods for the purpose of this white paper.*

[3] *The U.S. EIA defines degree days as a measure of how cold or warm a location is. Heating degree days (HDD) are a measure of how cold the temperature was on a given day or during a period of days. For example, a day with a mean temperature of 40°F has 25 HDD. Two such cold days in a row have a total of 50 HDD for the two-day period. Cooling degree days (CDD) are a measure of how hot the temperature was on a given day or during a period of days. A day with a mean temperature of 80°F has 15 CDD. If the next day has a mean temperature of 83°F, it has 18 CDD. The total CDD for the two days is 33 CDD.*

[4] *Nebraska was omitted by the models due to a lack of heterogeneity across the years, given its unicameral non-partisan legislature.*

TABLE 2. KEY VARIABLES AND DESCRIPTIVE STATISTICS

	Measure/ Units	Range	Mean	Standard Deviation
Climate Policy Index	Factor analyzed Index	-1.9 – 5.6	1.9	1.5
Real Income Growth Rate	Percentage	-0.4-6.5	2.4	1.3
Share of Population Living below FPL	Percentage	3.7-23.1	13.0	3.5
Population	Millions	0.6-39.5	6.2	7.1
Governor's Party	Party	Democratic/Republican/Independent	-	-
State Legislative Control	Party	Democratic/Republican/Split Control	-	-
President	Party	Democratic/Republican	-	-
Average Price of Electricity	Cents/ kWh	7.1-37.3	11.6	3.9
Average Price of Natural Gas	$ /thousand cubic feet	7.3-55.4	14.1	5.4
Annual Energy Production	Million MMBtu	4.9 X 10^{-5} – 20.4	1.5	2.6
LIHEAP Appropriation	Million $	4.6-537.3	72.2	72.9
Heating Degree Days	Days	2232-7304	4876.3	1584.2
Cooling Degree Days	Days	420-3112	1408.5	701.4

RESULTS

Given the panel structure of the data, a fixed effects model was utilized to account for the heterogeneity between states[5]. The results in Table 3 suggest that the Climate Policy Index is positively and significantly associated with the median energy burden. The effect size is small but positive, indicating that a one-unit change in Climate Policy Index results in a 0.01 unit increase in energy burden (standard error ≈ 0.005).

Therefore, greater scope and strength of climate policies in states have increased the median energy burden between 2010 and 2019, while controlling for other factors[6]. Table 3 presents the regression results for fixed effects models for different income groups. Hausman

TABLE 3. THE IMPACT OF CLIMATE POLICIES ON MEDIAN ENERGY BURDEN, 2010-2019

	Median Income
Climate Policy Index	0.0177***
Real Income Growth Rate	0.0106
Share of Population Living below FPL	0.0515***
Population	-0.0626
Governor's Party (Compared to Independent Governor)	
Republican	0.3342*
Democratic	0.4271**
State Legislative Control (Compared to Split Control)	
Republican	0.0651
Democratic	-0.0091
Democratic President	0.1606***
Average Price of Electricity	0.0415**
Average Price of Natural Gas	0.0028
Energy Production	-0.0140
LIHEAP Appropriation	0.0007
Heating Degree Days	7.41E-06
Cooling Degree Days	-0.0002*
Constant	1.2822*
R-squared	0.3694
*** p<0.001, ** p<0.01, * p<0.05	

[5] *To check for the model's robustness, the model estimates were compared to those of a random effects model using a Hausman test. The test returned a p-value of 0, thus resulting in the rejection of the null hypothesis because the random effects were likely correlated with one or more regressors. Therefore, the fixed effects model is preferred over the random effects model for the given data.*

[6] *To check for potential outliers and to ensure high energy-producing states are not skewing the results, the model was estimated with the exclusion of Alaska, California, Louisiana, Pennsylvania, Wyoming, West Virginia, and Texas. The substantive results remained the same. The regression results are included in Appendix C.*

TABLE 4. THE IMPACT OF CLIMATE POLICIES ON THE ENERGY BURDEN OF EACH INCOME GROUP, 2010-2019

	Low-Income	Middle-Income	High-Income
Climate Policy Index	0.0468*	0.0058*	0.0075*
Real Income Growth Rate	0.0312	0.0030	0.0043
Share of Population Living below FPL	0.1425***	0.0167***	0.0222***
Population	-0.1375	-0.0221	-0.0242
Governor's Party (Compared to Independent Governor)			
Republican	1.017***	0.1027***	0.1522***
Democratic	1.2542***	0.1331***	0.1922***
State Legislative Control (Compared to Split Control)			
Republican	0.1743	0.02197	0.0267
Democratic	-0.0071	-0.0026	-0.0044
Democratic President	0.4395***	0.0519***	0.0691***
Average Price of Electricity	0.1172*	0.0129*	0.0179*
Average Price of Natural Gas	0.0019	0.0009	0.0008
Energy Production	-0.0288	-0.0048	-0.0056
LIHEAP Appropriation	0.0021	0.0002	0.0003
Heating Degree Days	1.57E-05	3.63E-06	3.87E-06
Cooling Degree Days	-0.0007*	-7.85E-05	-0.0001
Constant	3.1747*	0.4288*	0.5276*
R-squared (within group)	0.3734	0.3633	0.3695
*** p<0.001, ** p<0.01, * p<0.05			

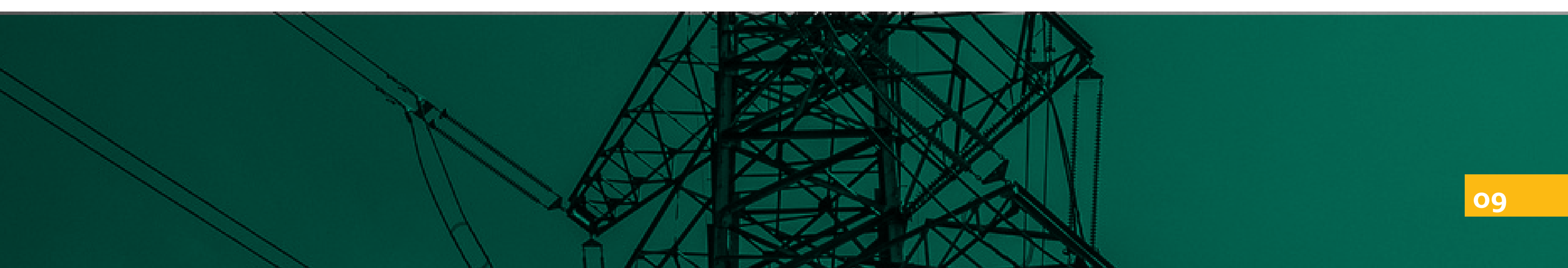
Test comparisons with random effects models in each of the cases revealed that the fixed effects model was preferred for the given data. The results indicate that Climate Policy Index is positively and significantly associated with energy burden across all income groups.

While the effect sizes are small, the most substantial impact is observed for the low-income. The effect size of climate policies on the median energy burden is 0.017, for the low-income is 0.047, for the middle-income is 0.005, and for the high-income is 0.007. Relatively, this indicates that the impact of climate policies on the energy burden for the low-income is four times higher than the median income. Similarly, the impact of climate policies on the energy burden for the low-income is eight times higher than the middle-income.

Lastly, the impact of climate policies on the energy burden for low-income communities is about six times higher than the high-income. Interestingly, with the smallest coefficient of 0.005, climate policies were found to have the lowest impact on the middle-income as compared to all other income groups and the median income. Therefore, greater scope and higher strength of climate policies in states have most substantially increased the energy burden for the low-income between 2010 and 2019, while controlling for other factors.

The results presented in Tables 3 and 4 are summarized in Figure 2.

Next, energy burden was found to be positively and significantly associated with the share of the population living below



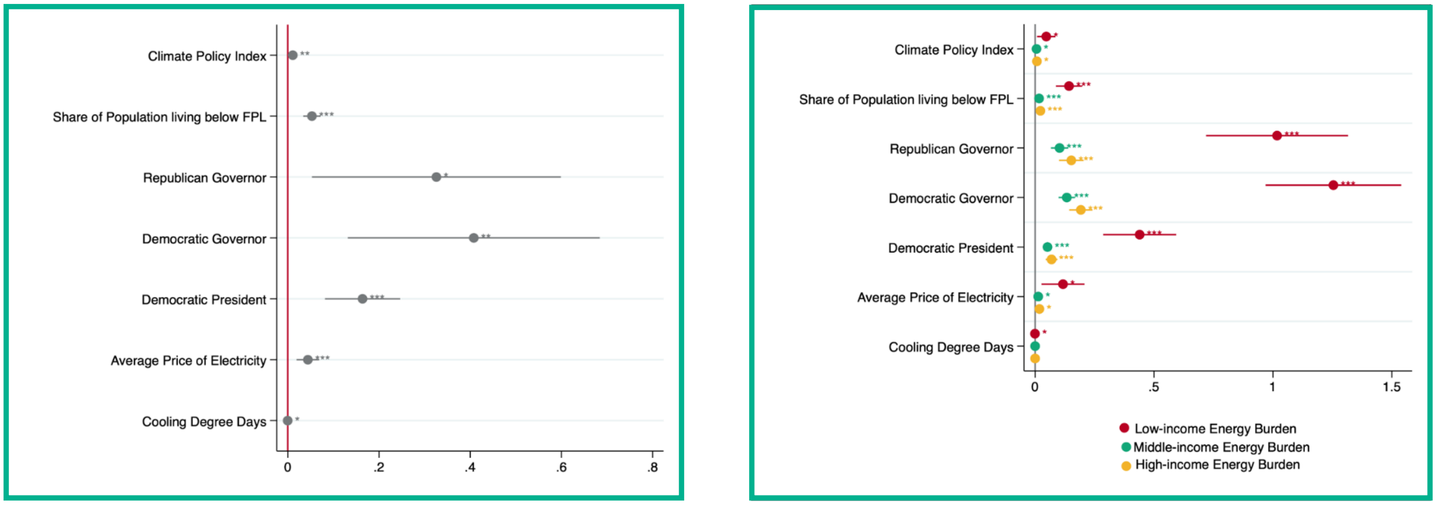


FIGURE 2. The Impact of Climate Policies on Median Energy Burden (top) and the Energy Burden across Low, Medium, and High-Income Communities (bottom), 2010-2019.

the federal poverty level, indicating that states with a larger share of low-income populations witness a substantial increase in their energy burden, thereby bolstering the evidence that low-income communities are experiencing disproportionately higher energy burdens. The energy burden was found to decrease as the state population increases. For a one million increase in population, the energy burden decreased by 0.06 units or a reduction of the order of 10^{-7} for a per person increase in population. The effect size was negligible and not statistically significant.

States with Democratic governors were found to have the highest energy burden, followed by those with Republican governors, relative to states with an Independent governor. The effect was statistically significant across all models, and the largest for low-income communities, wherein, in states with a Democratic governor, the low-income households were found to have a 1.2-unit higher energy burden as compared to states with an Independent governor, while those with a Republican governor were found to have a 1-unit higher energy burden as compared to states which have an Independent governor. The energy burden was also found to increase under a Democratic president as compared to a Republican president. The effect was statistically significant and largest for the low-income. Since the dataset includes values between 2010-2019, these results are potentially impacted by the 2007-2009 financial crisis and do not offer much heterogeneity in terms of presidential control. No measurable effects were observed for legislative control.

Finally, energy burden was found to be positively and significantly associated with the price of electricity across all models. Other policy, economic, and weather controls had a negligible effect size and were not statistically significant for any of the models.

DISCUSSION AND CONCLUSIONS

Income inequality and climate change are defining challenges of our times. Policies that simultaneously address and mitigate the impacts of both challenges have been difficult to develop, adopt, and sustain. When the Biden administration took office in January 2021, its key priorities were reducing income inequality and finding sustainable policy pathways to advance climate mitigation domestically, and U.S. climate leadership globally. Before climate action emerged as a federal priority, many states across the country instated several policies and regulations addressing climate change mitigation and emissions reduction, albeit, with varying scope and strength.

Panel data from all U.S. states between 2010-2019 evidenced that greater scope and higher strength of climate policies across states has increased the median energy burden. Across income groups, climate policies are increasing the energy burden most substantially for the low-income. The impact of climate policies on the energy burden for the low-income is four times higher than that on the median-income energy burden. When compared to middle-income communities, the impact of climate policies on the low-income is about eight times higher. Similarly, when compared to high-income communities, the impact of climate policies on the low-income is about six times higher.

The energy burden, across all income groups and especially for low-income communities, was found to be higher under Democratic governors and when a Democratic president is in office. The dataset spans ten years with limited variability in presidential control (one Democratic and one Republican president), but the findings for gubernatorial partisanship are interesting. While this is counterintuitive and the coefficients are relative, as most of the top

ten poorest states and the states that spend most on their energy bills are Republican, a combination of voting behavior, partisanship, ideology, energy consumption, utility rates and bills, geography, and when and how homes are constructed are likely at play. This work controls for many of these measures at the aggregate state level but lacks individual-level data.

A multi-level analysis of individual (voter) and aggregate (state) level data would help evaluate if Democratic governors truly have a regressive impact on energy burden over the years included in the analysis and if the partisan impacts hold over voter and state characteristics.

Energy equity and energy justice are central to mitigating income disparities and climate change. The regressive distributional outcomes of current climate policies will impact their political acceptability and reduce their likelihood of being sustained. Moreover, if electricity prices and energy burdens continue to increase, low-income Americans will find it increasingly challenging to afford electricity and have their energy demands fulfilled, pushing many from being energy-poor to energy-vulnerable.

APPENDIX A: SCOPE, STRENGTH AND SCALING OF POLICIES

CARBON PRICING

Current forms of carbon pricing across U.S. states only include cap-and-trade programs. No state or federal carbon tax has been adopted yet. Ten northeastern states are part of the Regional Greenhouse Gas Initiative (RGGI). It is the first mandatory regional cap-and-trade program between the states of Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, Vermont, and Virginia. In addition to this, California's cap-and-trade program is linked to the cap-and-trade in Quebec, Canada. Massachusetts has a separate state cap-and-trade program targeting the electricity sector, which runs parallel to the RGGI. States with no carbon pricing were scored the lowest, while those participating in the RGGI and implementing state-level cap-and-trade were scored the highest.

ELECTRICITY SECTOR PORTFOLIO STANDARD

Most electricity sector portfolio goals and standards were initiated with the dual objective of emissions reduction for climate change mitigation and supporting in-state renewable energy production to reduce the cost of electricity. States with a goal scored lower than states with statutory standards in place. Clean energy goals/standards which encourage low-carbon electricity generation from all eligible sources, including fossil fuels, were scored lower than renewable energy goals/standards which are more stringent and exclude fossil fuel-based energy. Instead, they are focused on a broad suite of renewable energy sources including wind, solar, hydro, geothermal, and biomass, and encourage reduced reliance on fossil fuels. Alternative fuel standards encourage alternative sources of thermal energy only and include production technologies such as combined heat and power (CHP) and energy-efficient steam technology. Alternative fuel standards, given their limited scope, were scored lower than clean energy and renewable portfolio standards.

CLIMATE ACTION PLAN

These plans typically include details of emissions targets, policy pathways, implementation strategies across multiple sectors of the economy, and broader economic and social goals. As of 2019, 23 states had released and enforced their climate action plans, eight states were updating their plans, and one state's plan was in the development stage. States with no plans scored the lowest, while those with released and enforced plans scored the highest.

ENERGY EFFICIENCY PLAN

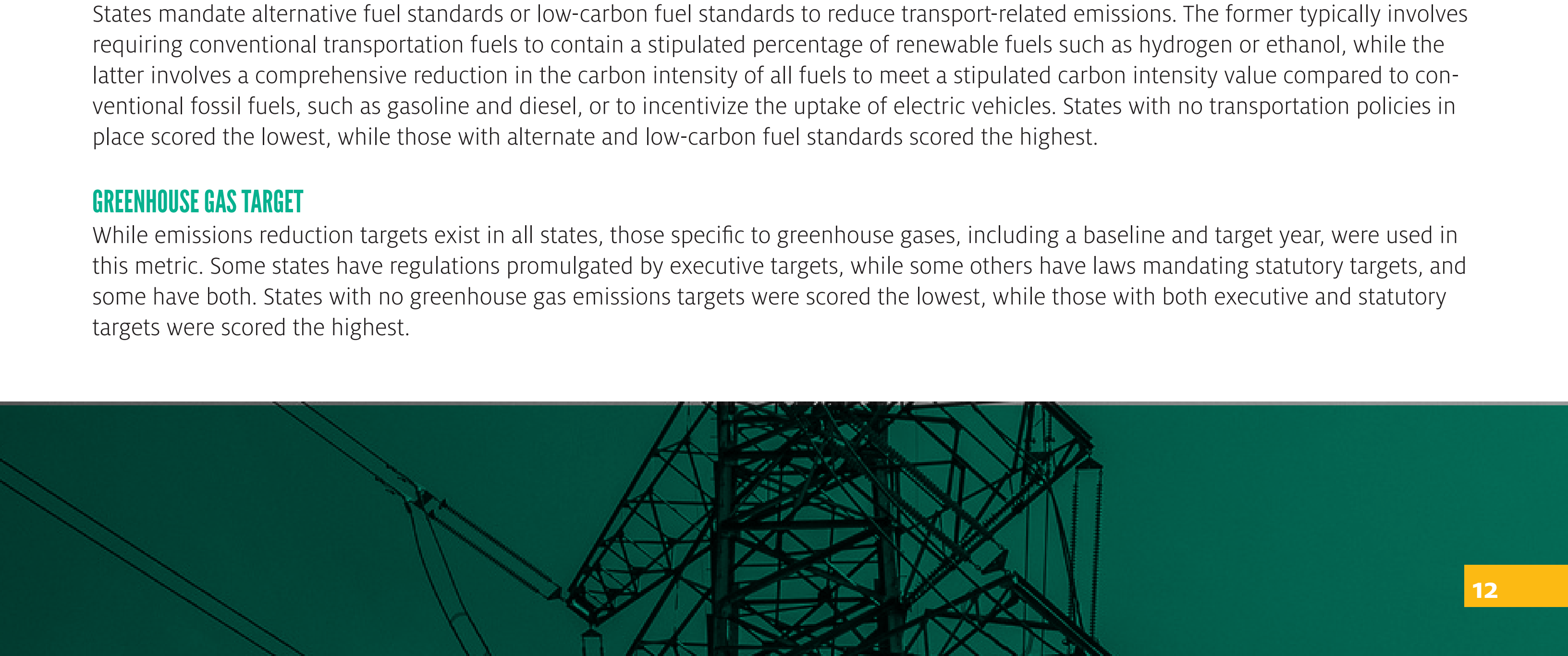
Most states have mandates and incentives to encourage energy efficiency. Two commonly adopted mechanisms are a lost revenue adjustment (LRA) program and decoupling. An LRA program allows rate adjustment such that a utility (natural gas or electricity) can recover any revenue that may be reduced because of energy efficiency programs, while decoupling allows regulators to make slight adjustments to utility rates such that the link between the amount of natural gas or electricity sold by a utility is not the basis for its revenue. Decoupling allows for utility rates to vary such that revenue is fully recovered, regardless of utility sales, thereby, protecting the utility against revenue loss through efficiency or other factors such as weather changes. While LRA requires utilities to pre-assess energy savings over a specific timeframe, decoupling does not mandate so. LRA does not allow for additional adjustments if the utility sells more than its assessment, while decoupling is adjusted to demand. Both can vary in scope and can be applied only to gas utilities or electricity utilities or both. States with no LRA or decoupling measures were scored lowest while those with decoupling for both gas and electricity utilities were scored the highest.

TRANSPORTATION POLICIES

States mandate alternative fuel standards or low-carbon fuel standards to reduce transport-related emissions. The former typically involves requiring conventional transportation fuels to contain a stipulated percentage of renewable fuels such as hydrogen or ethanol, while the latter involves a comprehensive reduction in the carbon intensity of all fuels to meet a stipulated carbon intensity value compared to conventional fossil fuels, such as gasoline and diesel, or to incentivize the uptake of electric vehicles. States with no transportation policies in place scored the lowest, while those with alternate and low-carbon fuel standards scored the highest.

GREENHOUSE GAS TARGET

While emissions reduction targets exist in all states, those specific to greenhouse gases, including a baseline and target year, were used in this metric. Some states have regulations promulgated by executive targets, while some others have laws mandating statutory targets, and some have both. States with no greenhouse gas emissions targets were scored the lowest, while those with both executive and statutory targets were scored the highest.



APPENDIX B: FACTOR ANALYSIS AND CLIMATE POLICY INDEX

TABLE 5. FACTOR LOADINGS OF POLICY ITEMS AND CLIMATE POLICY INDEX, 2010-2019

Policy Domain	N	Range	Factor Loading
Carbon Pricing	510	0-3	0.73
Energy Sector Portfolio Standards	510	0-6	0.67
Climate Action Plan	510	0-3	0.44
Energy Efficiency Policies	510	0-6	0.53
Transportation Policies	510	0-3	0.51
Greenhouse Gas Target	510	0-3	0.68

FIGURE 3. Climate Policy Index across the U.S. states between 2010 and 2019.

APPENDIX C: ADDITIONAL REGRESSION RESULTS

TABLE 6. REGRESSION RESULTS EXCLUDING ALASKA, CALIFORNIA, LOUISIANA, PENNSYLVANIA, WYOMING, WEST VIRGINIA, TEXAS

	Median Income – excluding the top seven energy-producing states
Climate Policy Index	0.0184***
Real Income Growth Rate	0.0141
Share of Population Living below FPL	0.0481***
Population	-0.0996
Governor's Party (Compared to Independent Governor)	
Republican	0.3651
Democratic	0.4921*
State Legislative Control (Compared to Split Control)	
Republican	0.0723
Democratic	0.0238
Democratic President	0.1695***
Average Price of Electricity	0.0424**
Average Price of Natural Gas	0.0065
Energy Production	-0.0507
LIHEAP Appropriation	0.0005
Heating Degree Days	-8.16E-06
Cooling Degree Days	-0.0002*
Constant	1.4512*
R-squared	0.3677
*** p<0.001, ** p<0.01, * p<0.05	

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