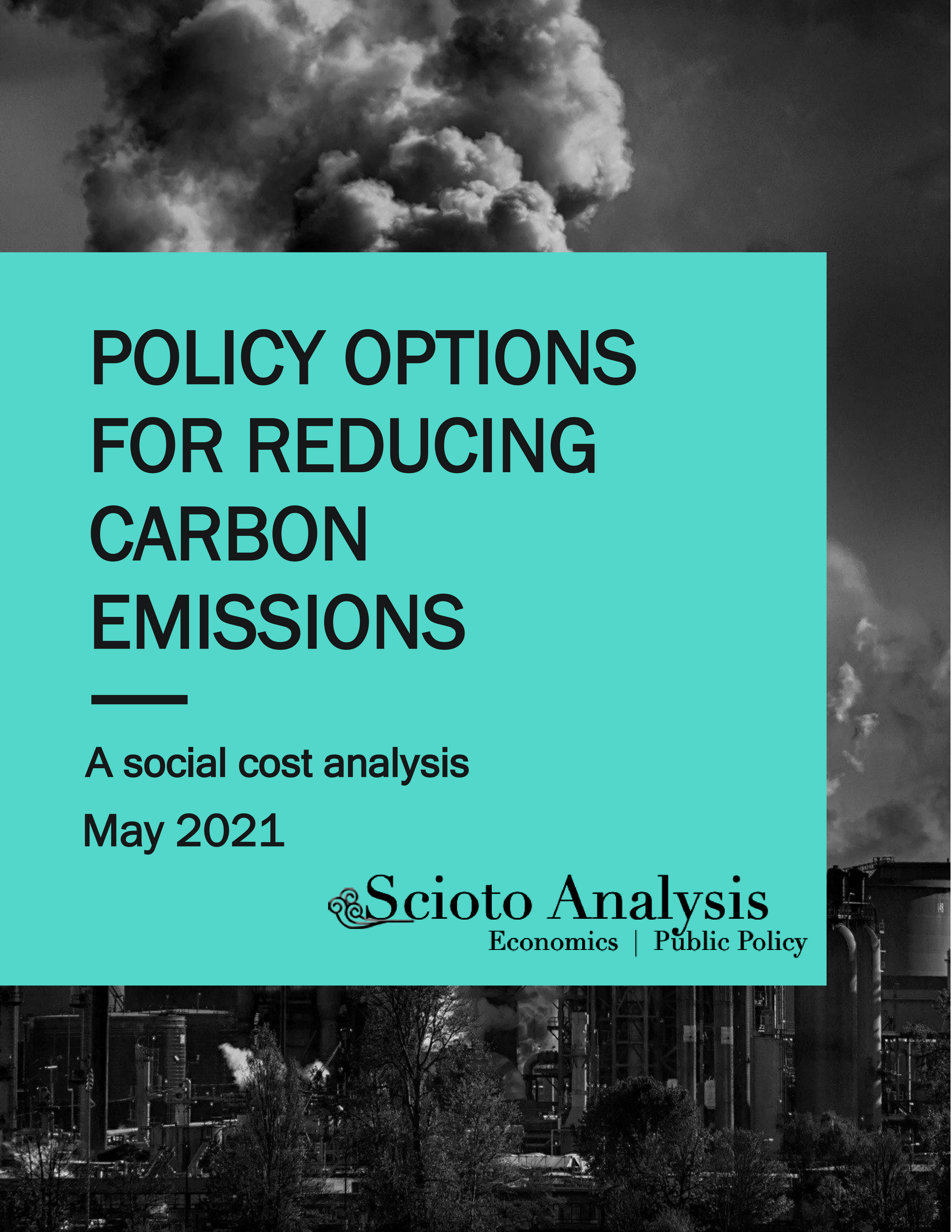


POLICY OPTIONS FOR REDUCING CARBON EMISSIONS

A social cost analysis

May 2021

Scioto Analysis
Economics | Public Policy

Executive Summary

This study is an analysis of state-level policy options for abating carbon emissions from the energy sector. We consider three types of policies — Renewable Portfolio Standards (RPS), cap-and-trade, and carbon tax — and compare the efficacy of each in reducing the economic impact of carbon emissions over a thirty-year period. While we project a strong cap and trade policy to be marginally more effective than alternatives, renewable portfolio standards, cap and trade, and carbon tax policies all have the potential to drastically reduce state carbon emissions. Even a conservative policy mirroring the status quo in Michigan — a renewable portfolio standard of 25% from 2026 onwards — substantially reduces the projected social cost of carbon emissions through 2050.

Our study uses the U.S Energy Information Administration's data on energy production in Ohio between 2008-2018, which includes the distribution of energy among different sources. Based on energy production trends and the current Renewable Portfolio Standards (RPS), we project state energy production trends and the amount of CO2 emitted each year from 2021 to 2050. After discounting the status quo policy projected costs of carbon emissions and the relative reduction in costs with a new policy implementation, we determine a cap of 127.4 million metric tons in 2021, decreasing by 2.275 million metric tons each year, to be the most effective carbon abatement policy for Ohio when measured in the social benefits of carbon abatement.

Background

The Paris Agreement, signed in 2016 within the United Nations Framework Convention on Climate Change, aims to reduce the global greenhouse gas emissions to keep global warming levels at below 2℃ and pursue efforts to limit them to 1.5℃. To achieve this goal, countries have set domestic standards and limits on carbon emissions. In April 2021, President Biden announced that the United States aims to achieve a 50-52% reduction from 2005 levels in economy-wide net greenhouse gas pollution in 2030.[1]

If Biden follows the lead of the last president to enact significant carbon abatement, the burden for achieving national benchmarks will fall on state governments, who would be required to enact policies to reduce their emissions. Our analysis attempts to provide a reference for comparing the efficacy of different carbon abatement policies and their economic impact for the state of Ohio. By 'efficacy' we mean the amount by which carbon emissions are abated, and the corresponding economic impact is the social cost of these emissions calculated using generally accepted estimates of the social cost of carbon.

The status quo policy in Ohio is a renewable portfolio standard of 6.5% (as of 2021) increasing by 0.5% until 2026, meaning 8.5% of the state's energy required to be produced from renewable sources from 2026 onwards.[2]

[1] "FACT SHEET: President Biden Sets 2030 Greenhouse Gas Pollution Reduction Target Aimed at Creating Good-Paying Union Jobs and Securing U.S. Leadership on Clean Energy Technologies." The White House. The United States Government, April 22, 2021. https://www.whitehouse.gov/briefing-room/statements-releases/2021/04/22/fact-sheet-president-biden-sets-2030-greenhouse-gas-pollution-reduction-target-aimed-at-creating-good-paying-union-jobs-and-securing-u-s-leadership-on-clean-energy-technologies/.

[2] "Section 4928.64: Electric Distribution Utility to Provide Electricity from Alternative Energy Resources." Section 4928.64 - Ohio Revised Code | Ohio Laws. Accessed May 4, 2021. https://codes.ohio.gov/ohio-revised-code/section-4928.64.

Standing

Since the social cost of carbon is a globally applicable measure, the economic impacts calculated in our study have a global character as well. However, since the costs we calculate are based on carbon emissions by Ohio's energy sector, this globally applicable model includes the economic impact on the residents of Ohio.

Methodology

We perform a standard cost-benefit analysis in our study based on the best practices in Boardman et al's *Cost-Benefit Analysis: Concepts and Practice* and the *Ohio Handbook of Cost-Benefit Analysis*. We estimate benefits of policy alternatives by estimating the amount of carbon each alternative would abate in a given year, correcting the current market failure caused by external costs of carbon emissions. We then monetize the cost of that carbon using a social cost of carbon and discount the benefits to present value. We also conduct sensitivity analysis through Monte Carlo simulation to test the precision of our estimates.

Policy Options

1. Renewable Portfolio Standards (RPS)

Renewable Portfolio Standards require energy suppliers to produce a certain percentage of energy from renewable energy sources. For instance, a renewable portfolio standard requirement of 15% requires 15% of supplied energy (in kilowatt hours) to come from renewable sources. Nationwide studies on state renewable portfolio standards find renewable portfolio standards can create a foundation for a national market for renewable energy, which can drive job creation and economic growth.[3]

- **a.** **Strong RPS:** The strong renewable portfolio standard we consider is reflective of the current RPS portfolio in Maine, mandating **80% of Ohio's electricity coming from renewable sources by 2030, 100% by 2050.**

- **b.** **Weak RPS:** The weak renewable portfolio standard we consider is the target acceptable to utility providers in Michigan, as the state seeks to revise its own renewable portfolio standard: to hit 25% by 2025 and level off from then onwards.[4] Our policy alternative is to achieve a **25% renewable portfolio standard by 2026**.

2. Cap-and-Trade

Cap-and-trade is a market-based policy that sets a limit on the total amount of carbon that can be emitted, and this amount is then split into 'allowances.' Emitters, mostly power companies, purchase the allowances from the state through an auction, buying the right to emit a certain amount of carbon. The price of allowances is thus decided by the market, with the quantity of emissions fixed by the

[3] Leon, Warren. "The State of State Renewable Portfolio Standards," June 2013. https://www.cesa.org/wp-content/uploads/State-of-State-RPSs-Report-Final-June-2013.pdf.

[4] Balaskovitz, Andy, and Energy News Network February 5 Andy Balaskovitz. "Michigan's Renewable Energy Law Levels off next Year. What's next?" Energy News Network, February 5, 2020. https://energynews.us/2020/02/05/michigans-renewable-energy-law-levels-off-next-year-whats-next/.

state.[5] Our cap-and-trade policy alternatives are adopted from the Regional Greenhouse Gas Initiative (RGGI), a cooperative effort among eleven northeastern states to reduce carbon emissions through a market-based cap-and-trade program. We determine a strong cap for Ohio as a per capita calculation from the regional cap; the weak cap is similarly determined, but from an unrevised higher regional cap.[6]

a. **Strong Cap:** We analyze a strong cap set at **127.4 million metric tons in 2021, decreasing by 2.275 million metric tons each year.**

b. **Weak Cap:** We analyze a weaker cap to be set at **203 million metric tons in 2021, decreasing by 2.275 million metric tons each year.**

3. Carbon Tax

A carbon tax is a similar approach to cap-and-trade, except in this case emitters are charged a dollar value per metric ton of carbon emissions. The pricing of emissions disincentivizes carbon emissions by making them more expensive and driving them down. Thus, in this case, the price is set by the state and the quantity of emissions is then determined by the market.[7] Our carbon tax policies are reflective of carbon pricing bills proposed in the 116th and 117th Congress: the strong tax is inspired by the Consumers REBATE Act, while a weaker tax is inspired by the bipartisan Energy Innovation and Carbon Dividend Act.[8]

a. **Strong Tax:** We analyze a strong tax at the rate of **$25 per metric tons in 2021, increasing by $10 + inflation each year thereafter.**

b. **Weak Tax:** We analyze a weak tax at the rate of **$15 per metric tons in 2021, $25 in 2022, increasing by 5.5% each year.**

Impacts

Here, we provide a brief qualitative overview of the impact of carbon emissions pertaining to Ohio residents and the Midwest region as a whole, based on the Third National Climate Assessment report before presenting the social cost of carbon, the most effectively quantified and monetized estimate of the cost of carbon emissions.

The major carbon emission impact categories for Ohio residents involve health risks, infrastructure damage, and food insecurity. Health risks like frequency of respiratory illnesses (from air pollution), heat stress, airborne and waterborne diseases, and illnesses from extreme weather increase with increasing carbon emissions. Moreover, the vulnerability of physical infrastructure is compounded by rising sea levels, storm surges, heat waves, and extreme weather events, stressing or even overwhelming essential services. Extreme weather events can affect energy production and delivery facilities, causing supply disruptions and affecting other infrastructure that depends on energy supply;

[5] "How Cap and Trade Works." Environmental Defense Fund. Accessed May 4, 2021. https://www.edf.org/climate/how-cap-and-trade-works.

[6] "Elements of RGGI." Elements of RGGI | RGGI, Inc. Accessed May 4, 2021. https://www.rggi.org/program-overview-and-design/elements.

[7] "Carbon Pricing 101." Resources for the Future. Accessed May 4, 2021. https://www.rff.org/publications/explainers/carbon-pricing-101/.

[8] "Carbon Pricing Bill Tracker." Resources for the Future. Accessed May 4, 2021. https://www.rff.org/publications/data-tools/carbon-pricing-bill-tracker/.

the Texas power grid failure is a recent example of such an event. Finally, carbon emissions can disrupt agricultural production, causing regions to experience declines in crop and livestock production from increased stress due to weeds, diseases, and insect pests. This has the potential for culminating into food insecurity crises through changes in crop yields and food prices and effects on food processing, storage, transportation, and retailing.

Quantifying Impacts: The Social Cost of Carbon

The standard measure for translating the impacts of climate change into economic terminology is the social cost of carbon (SCC). The SCC is a dollar value estimate of economic damages incurred from emitting a ton of carbon into the atmosphere.[9] We use the SCC to quantify the dollar value effect of implementing a carbon abatement policy (Policy A) using the following equation:

Benefits of Policy A = (*Status Quo Carbon Emissions* x *SCC*) - (*Carbon Emissions with Policy A* x *SCC*)

Projecting Status Quo Outcomes

We project the total economic damage from carbon emissions based on the U.S Energy Information Administration's data on Ohio's energy production from 2008-2018. The EIA energy production data is broken down to reflect the contribution of each energy source towards the total energy produced for each year.[10] These energy sources are listed in table 1.

Non-Renewable Energy Sources (Fossil Fuels)	Renewable Energy Sources	Other
Coal	Biofuels	Nuclear Power[11]
Natural Gas	Wood and Waste	
Crude Oil	Hydroelectric Power, Wind, Solar, and Geothermal Energy	

Table 1: Sources of electrical energy production in Ohio

Based on data on the energy production from fossil fuels, we estimate the CO2 emitted from each source using the conversion values listed in table 2.

[9] "Social Cost of Carbon 101." Resources for the Future. Accessed May 4, 2021. https://www.rff.org/publications/explainers/social-cost-carbon-101/.

[10] "Primary Energy Production Estimates in Trillion Btu, Ohio, 1960-2018." U.S Energy Information Administration, n.d. https://www.eia.gov/state/seds/sep_prod/pdf/PT2_OH.pdf.

[11] Although a clean energy source, Nuclear Power is not renewable, and thus not considered a contributor to RPS portfolios.

Fossil Fuel	CO2 (in pounds) emitted per Btu
Coal	208
Natural Gas	117
Crude Oil	161.6

Table 2: Pounds of CO2 emitted per Btu of energy produced from fossil fuels[12]

We further convert CO2 emission data from pounds to metric tons, with one pound equaling 0.000453592 metric tons.

From the EIA data, we find that Ohio's total energy production increased by 220% between 2008-2018, roughly amounting to a 22% increase per year. This increase was accompanied by a relative decline in energy production from coal, an increase in production from natural gas, and an average increase in energy output of 0.5% from nuclear power plants. Since we expect these trends to continue, we take the first year of every decade as a base year, projecting the energy production by adding 22% of the base year to each successive year in that decade. The accuracy of our projections is reinforced by emulating technology-related changes in trends that become apparent over a decade. However, it is worth noting that the immediate period after 2008 was characterized by strong post-recession economic growth, meaning that our projection for the status quo carbon emissions (and thus their economic impact) might be higher than what we would actually expect.

Finally, we determine the corresponding energy produced from renewable sources for each year--until 2050--using the following formula:

Energy produced from fossil fuels = Total energy produced - (Energy produced from renewable sources + Energy produced from nuclear power)

Policy Impacts

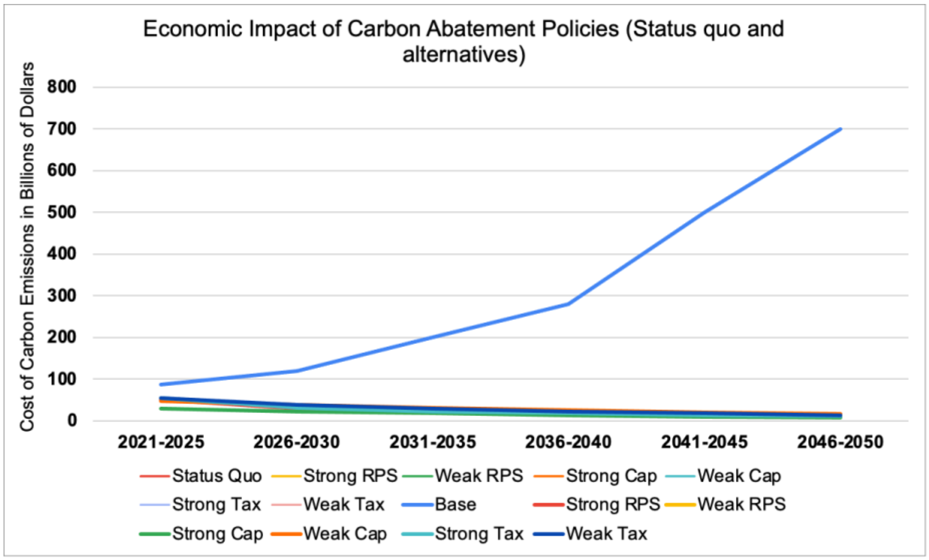


Table 3: Economic Impact of Carbon Abatement Policies from 2021-2050

[12] Frequently Asked Questions (FAQs) - U.S. Energy Information Administration (EIA). Accessed May 4, 2021. https://www.eia.gov/tools/faqs/faq.php?id=73&t=11.

Comparing the policy alternatives to the status quo (Table 3), a clear initial inference is that any alternative significantly reduces the economic impact of carbon emissions. Table 4 below shows a relative comparison of the alternatives themselves. (Appendix A shows a table of our projections for each policy, for every five year period from 2021 onwards, until 2050.)

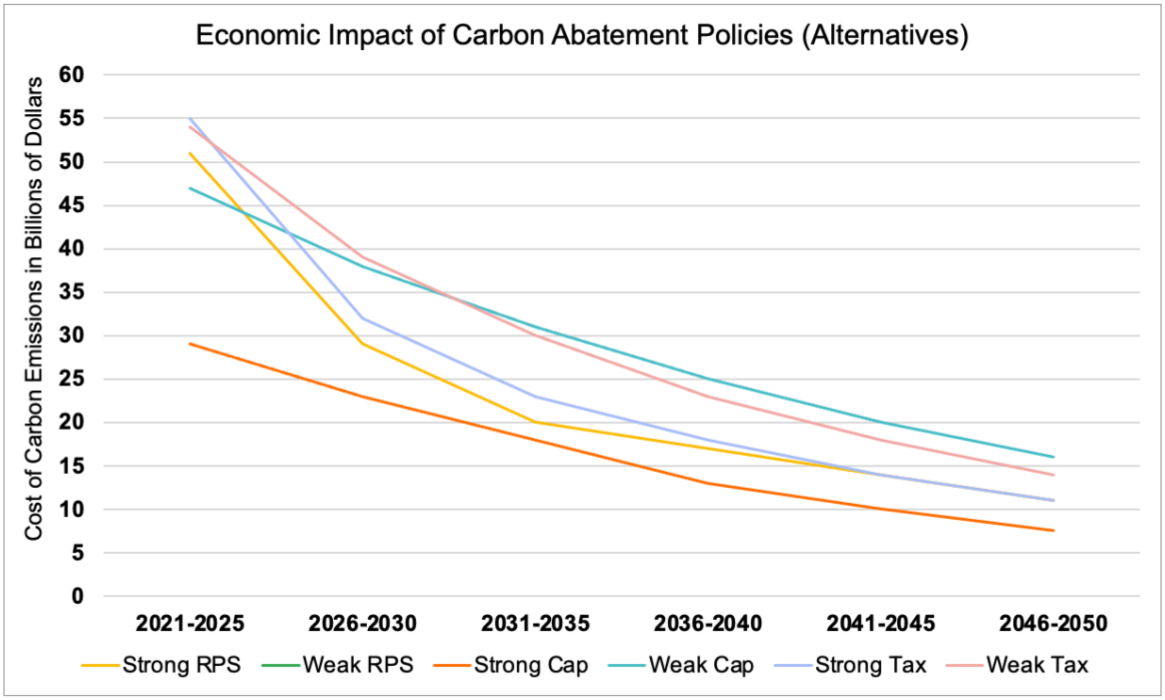


Table 4: Economic Impact of Policy Alternatives from 2021-2050

The most effective policy for abating carbon emissions and their consequent economic damages, according to our model, is a cap of **127.4 million metric tons in 2021, decreasing by 2.275 million metric tons each year.** However, in relation to the status quo, even the 'least effective' policy — a 25% renewable portfolio standard by 2026 — reduces the total projected economic damages by **88.2%**.

Sensitivity Analysis

First, it is worth noting that assuming much lower baseline carbon emissions will result in large reductions in cost of carbon. We will still see around $500 billion in benefits from our policy alternatives even if the status quo projections increase at half the rate.

We rigorously test the accuracy of our results by conducting a Monte Carlo simulation of our model by varying the social cost of carbon, discount rate, and the price elasticity of supply for electricity. Table 4 shows the parameters we vary, and by how much, in our simulation.

Parameter	Lower Bound	Accepted Value	Upper Bound
Social Cost of Carbon	$30	$50	$51
Discount Rate	2.5%	3%	11%
Price Elasticity of Supply for Electricity[13]	-0.2	-0.4	-0.6

Table 5: Variation of Parameters for Sensitivity Analysis (Monte Carlo Simulation)

Social Cost of Carbon

As mentioned earlier, $50 per metric ton is the most widely accepted value for the social cost of carbon; we set our upper bound at $51, given that it is the Biden administration's temporary readjustment for the United States. The lower bound of $30 is a conservative estimate.

Discount Rate

We set our discount rate at 3% since this is the most commonly accepted discount rate for the social cost of carbon. The lower bound of 2.5% is the lower estimate used in the US, and is close to the discount rate that a number of economists agree upon.[14] A conservative discount rate, as proposed by the Heritage Foundation, is considered to be around 7%; we place our higher bound at a conservative estimate of 11%.[15]

Price Elasticity of Supply for Electricity

Studies that seek to estimate the price elasticity of supply for electricity disagree considerably, with elasticities fluctuating between -0.1 and -0.6. Given this, we fix our accepted value at -0.4 (which reflects the elasticity of supply for residential areas), and choose our lower and upper bounds at -0.2 and -0.6 to include different sectors and long run elasticities.

We vary each of the parameters for our base projections as well as the projections for our policy alternatives. Our Monte Carlo simulation is used to calculate the impact of our policy alternatives in terms of the dollar value of the net costs displaced. This can be described by the following formula:

Efficacy of Policy A in Reducing the Impact of Carbon Emissions = Economic Impact of Carbon Emissions Based on the Status Quo - Economic Impact of Carbon Emissions Based with Policy A

Thus, the dollar values in Table 5 for each policy is the amount by which the status quo economic damages are reduced.

[13] Burke, Paul J., and Ashani Abayasekara. "The Price Elasticity of Electricity Demand in the United States: A Three-Dimensional Analysis," n.d. https://cama.crawford.anu.edu.au/sites/default/files/publication/cama_crawford_anu_edu_au/2017-08/50_2017_burke_abayasekara_0.pdf.

[14] "Q&A: The Social Cost of Carbon." Carbon Brief, February 8, 2019. https://www.carbonbrief.org/qa-social-cost-carbon.

[15] Kreutzer, David. "Discounting Climate Costs." The Heritage Foundation. Accessed May 7, 2021. https://www.heritage.org/environment/report/discounting-climate-costs.

Carbon Abatement Policy	**Low Estimate**	**Expected Value**	**High Estimate**
Renewable Portfolio Standard: 80% by 2030; 100% by 2050	$670 billion	$900 billion	$1 trillion
Renewable Portfolio Standard: 25% by 2026	$650 billion	$850 billion	$1 trillion
Cap-and-Trade: 127.4 metric tons in 2021, declining by 2.275 metric tons every year	$700 billion	$920 billion	$1 trillion
Cap-and-Trade: 203 metric tons in 2021, declining by 2.275 metric tons every year	$650 billion	$880 billion	$1 trillion
Carbon Tax: $25 per metric tons in 2021, increasing by $10 + inflation each year thereafter	$650 billion	$890 billion	$1 trillion
Carbon Tax: $15 per metric tons in 2021, $25 in 2022, increasing by 5.5% each year	$650 billion	$880 billion	$1 trillion

Table 6: Monte Carlo Simulation Results

Appendix A: Economic Impact of Carbon Abatement Policies (Table)

Table 3 shows the total economic impact of carbon emissions, for each policy, in five-year periods from 2021 to 2050. These costs are discounted at a rate of 3%, which is the average of prominent globally accepted discount rates for the social cost of carbon.[16] In this table, the following abbreviations are used to refer to the six status quo alternatives analyzed in this study.

- **RPS 1** = Renewable portfolio standard of 80% by 2030 and 100% by 2050
- **RPS 2** = Renewable portfolio standard of 25% by 2026
- **CnT 1** = Emission cap of 127.4 metric tons in 2021, decreasing by 2.275 metric tons each year
- **CnT 2** = Emission cap of 203 metric tons in 2021, decreasing by 2.275 metric tons each year
- **Tax 1** = $25 per metric tons in 2021, increasing by $10 + inflation each year thereafter
- **Tax 2** = $15 per metric tons in 2021, $25 in 2022, increasing by 5.5% each year

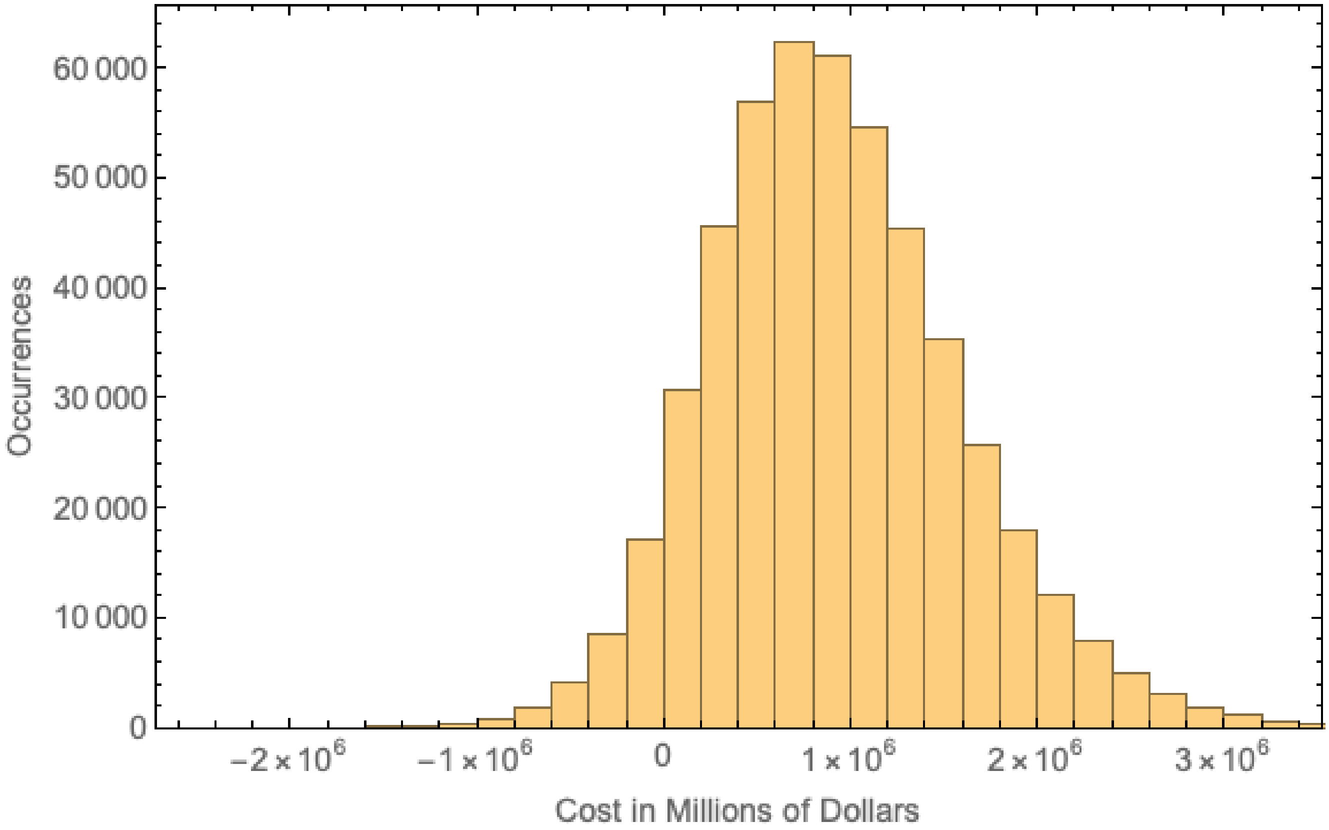
Period	Status Quo (in billions of dollars)	Renewable Portfolio Standard (in billions of dollars)		Cap-and-Trade (in billions of dollars)		Carbon Tax (in billions of dollars)	
		RPS 1	RPS 2	CnT 1	CnT 2	Tax 1	Tax 2
2021-2025	$88	$51	$57	$29	$47	$55	$54
2026-2030	$120	$29	$44	$23	$38	$32	$39
2031-2035	$200	$20	$47	$18	$31	$23	$30
2036-2040	$280	$17	$32	$13	$25	$18	$23
2041-2045	$500	$14	$28	$10	$20	$14	$18
2046-2050	$700	$11	$24	$7.5	$16	$11	$14
2021-50	$1800	$140	$222	$100	$177	$153	$180

Table 7: Projected Economic Impact of Carbon Emissions with Policy Alternatives in Place (Relative to the Status Quo)

[16] "Q&A: The Social Cost of Carbon." Carbon Brief, February 8, 2019. https://www.carbonbrief.org/qa-social-cost-carbon.

Appendix B: Monte Carlo Simulation

The figure below is a visualization of our Monte Carlo simulation for the strong cap-and-trade policy alternative. The exact expected value here is $922.481 billion.



Acknowledgements

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