PUT A PRICE ON POLLUTION

REDUCING CARBON DIOXIDE EMISSIONS IN MARYLAND

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DISCLAIMER

The author conducted this study as part of the program of professional education at the Frank Batten School of Leadership and Public Policy, University of Virginia. This paper is submitted in partial fulfillment of the course requirements for the Master of Public Policy degree. The judgments and conclusions are solely those of the author, and are not necessarily endorsed by the Batten School, by the University of Virginia, or by any other entity.

Honor Pledge:

On my honor, as a student, I have neither given nor received unauthorized aid on this assignment.

Lena Lewis

ACRONYMS

AB 32 = California cap and trade

BAU = Business as usual

BC = British Columbia

BTU = British Thermal Unit

CCAN = Chesapeake Climate Action Network

CO_2 = Carbon dioxide (also referred to as carbon emissions)

CTAM = Carbon Tax Assessment Model

DC = District of Columbia

EPA = Environmental Protection Agency

EIA = Energy Information Administration

GDP = Gross Domestic Product

HB 939 = Maryland House of Delegates Bill 939, 2018 Session (also known as RCCCI)

kg = kilogram

MD = Maryland

mpg = miles per gallon

mph = miles per hour

mt = metric ton (all references to tons in this analysis are metric tons, not short tons)

Mmt = millions of metric tons

$mtCO_2$ = metric tons of carbon dioxide emissions

NSEE = National Surveys on Energy and the Environment

RCCCI = Regional Carbon Cost Collective Initiative (also known as House Bill 939)

RGGI = Regional Greenhouse Gas Initiative

RPS = Renewable Energy Portfolio Standard

EXECUTIVE SUMMARY

MARYLAND MUST REDUCE ITS CARBON DIOXIDE EMISSIONS BY 40% OF 2006 LEVELS BY 2030 TO UPHOLD ITS COMMITMENT TO THE PRINCIPLES OF THE PARIS CLIMATE AGREEMENT.

By state law, Maryland must reduce its greenhouse gas emissions by 40% of 2006 levels by 2030 (SB323, 2016). Though Maryland already has many policies and programs to reduce greenhouse gas emissions, their collective effect will fall short of the goal (Hug, 2017). The Chesapeake Climate Action Network (CCAN) should advocate for a carbon emission reduction policy that will achieve the goal of 40% reductions in a manner that is cost-effective, simple in design, and transparent. The best carbon reduction policy will buffer low-income residents against the added financial burden of energy costs. It will also amplify Maryland's position as a leader on climate change by encouraging other states and nations to adopt similar policies.

Environmental economists are in consensus that the most economically efficient way to reduce carbon emissions is to put a price on carbon. **When people have to pay to pollute, they innovate ways to pollute less.**

In this report, I analyze three different carbon pricing plans and compare them to a Business As Usual (BAU) scenario for Maryland between the years of 2020 and 2030.

- Option 1: Maryland would adopt a **carbon fee and dividend based on the Regional Carbon Cost Collective Initiative (RCCCI)** proposal, which increases the carbon fee by **$5** per year.
- Option 2: Maryland would adopt a carbon fee and dividend program similar to the Climate and Community Investment Act of DC proposal, which increases the carbon fee by $10 per year.
- Option 3: Maryland would expand its carbon cap and trade policy by **leaving the Regional Greenhouse Gas Initiative (RGGI) and linking with California's carbon market**. RGGI's cap covers carbon emissions only from large power plants within RGGI states. California's cap covers all fossil fuels and electricity imported from out-of-state (CA §95852).

EXPAND CAP AND TRADE

Based on my analysis, CCAN should support expanding cap and trade for Maryland. This is the boldest option and would require the most legwork to build a coalition of support. The effort would be well spent because expanding cap and trade would **exceed Maryland's goal of carbon emission reductions at the lowest cost to Maryland residents and businesses.**

Because a carbon price would be a new expense for people who purchase gasoline, I evaluated the impact of a carbon price on spending and driving habits of Maryland drivers. The results give further support to the Expand-Cap-and-Trade option and point to productive ways to spend some of the revenue.

I recommend that revenue from the auction of carbon allowances be allocated such that

- **50**% is **rebated** to Maryland residents
- **20**% is used to offset lower **corporate taxes**.
- **30%** is **invested** both in infrastructure that lowers gasoline consumption and grants that improve energy efficiency for low-income households.

Table 1 on the next page summarizes my analysis. In the rest of this report, I explain the reasoning behind my recommendation and suggest methods for building a broad coalition of support for Expanding Cap and Trade in Maryland.

Table 1: Outcomes Matrix Summarizing Analysis of the Criteria for All Options

	Criteria	Business As Usual	Slow-rise Carbon Fee-and-Dividend	Fast-rise Carbon Fee-and-Dividend	Expand Cap-and-Trade
Environmental	Percent carbon dioxide emissions lowered in 2030 (2006 Baseline)	22%	33%	41%	47%
Economic	Cost of Expenditures per ton of CO2 avoided (Net Present Value at 7% discount rate, compared to BAU) (lower is better)	N/A	$480	$484	$143
	Additional cost of gallon of gasoline in 2030	$0	$0.40	$1.02	$0.31
	Miles people are willing to drive to avoid the carbon fee on gasoline in 2030 (lower is better)	0	4.6	11.7	3.5
Feasibility	Rank of public support for this plan	Highest	Second Highest	Lowest	Second Lowest
	Partisan support	More Republican than Democrat support	Majority of Democrats support this plan, and Minority of Republicans	More Democrats support this plan than Republicans	No partisan difference

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GLOSSARY

Carbon fee: In this paper, carbon free is synonymous with “carbon tax.” A tax on carbon dioxide emissions from fuel sources, usually limited to fossil fuels. Users of fuels that emit more carbon dioxide per unit of energy (e.g. coal) are charged higher fees than users of fuels emitting less carbon dioxide (e.g. natural gas).

Cap and trade: Also known as a carbon market or tradable emissions permits. The government sets a limit, or cap, on the tons of carbon dioxide emissions allowed. Firms wishing to emit carbon dioxide must acquire one allowance for each ton of carbon dioxide emitted. Firms that can reduce their own emissions can sell their allowances to other firms, thereby earning money through reducing their emissions. Over time, the government lowers the cap on emissions. Consequently, the price of emissions increases and the financial incentive to find alternative energy sources increases.

Climate & Community Reinvestment Act of DC: A proposed carbon fee and dividend policy for Washington, DC. It would begin at \$20/mtCO_2 and increase by \$10/year until leveling off at \$150/mtCO_2.

Complementary policies: These policies are intended to increase environmental benefits above those achieved by other policies already in place.

Fee-and-dividend: A model of carbon fee, or tax, that returns the revenue generated through a flat rebate. The amount of money collected through the carbon tax would be divided evenly among every tax payer. Thus, people whose activities result in lower carbon emissions will receive a higher rebate than they spent on carbon taxes. This dividend is intended to offset the higher burden placed on low-income households by a carbon tax.

Progressive: A policy that has a more positive impact on low-income people than on high-income people. For example, a carbon fee-and-dividend policy that returns a higher dividend to low-income households than to high-income households is progressive.

Regional Carbon Cost Collective Initiative (RCCCI): A proposed carbon fee-and-dividend policy outlined in Maryland House of Delegates Bill 939 in the 2018 General Assembly section. It would begin at \$15/ mtCO_2 and increase by \$5/year until leveling off at \$45/mtCO_2.

Regional Greenhouse Gas Initiative (RGGI): This is a carbon cap-and-trade program in which Maryland participates along with eight other northeastern states. The cap covers power plants that have a capacity of at least 25 megawatts. Since RGGI began in began in 2009, it has reduced carbon emissions from the states' power sector by approximately 15%. New Jersey is scheduled to join as a tenth participant, and Virginia is likely to link its own cap-and-trade program to RGGI within the next few years.

Regressive: A policy that has a more negative impact on low-income people than on high-income people. For example, a revenue-neutral carbon fee that is used entirely to lower corporate taxes is regressive. The carbon fee will be a higher percent of the budget for low-income households, while the corporate tax break will benefit higher-income households.

Renewable Energy Portfolio Standard (RPS): A state requirement that the power sector produce a certain percent of its electricity from renewable sources.

Revenue-neutral: The amount of revenue generated through a new tax is completely offset through revenue reductions in other areas of the tax code, or through returning the revenue to taxpayers.

Social cost of carbon: The cost to society of burning carbon-based fuels. Because this cost is dissipated worldwide and into the future, it is hard to quantify. It includes damage caused by storms, droughts, floods, sea level rise, and heat waves. It also includes increased health care costs. In this report, I use \$40 per metric ton of CO_2 (\$40/mtCO_2) as the social cost of carbon (EPA, 2017).

THE CHALLENGE FACING MARYLAND

Maryland must reduce its carbon dioxide emissions by 40% of 2006 levels by 2030 to uphold its commitment to the principles of the Paris Climate Agreement.

Climate change presents the human race with a problem unlike any we have faced before. It is a problem that can only be fixed through worldwide collective effort. If we fail to substantially reduce our greenhouse gas emissions within the next couple of decades, our descendants will likely face a world that is on average 7.6ºF hotter by the end of this century ("Climate Scorecard," 2018). This future is not inevitable. In order to avoid the worst impacts of climate change, scientists estimate that we must keep the average global temperature from rising more than 3.6ºF above preindustrial levels (United Nations Framework on Climate Change, 2015). To achieve that goal, 195 nations at the 2015 United Nations Climate Change Conference in Paris agreed to collectively cut greenhouse gas emissions.

Though the Trump Administration backed down from the pledges made in Paris, at least 15 states independently declared their intention to uphold the principles of the Paris Climate Agreement (Dance, 2018). Maryland is one of those states. The goal of Maryland's 2016 Reauthorized Greenhouse Gas Emission Reduction Act is to reduce the state's greenhouse gas emissions by 40% of 2006 levels by the year 2030 ("HB0610 Summary 2016 Regular Session," 2017). Carbon dioxide is the greenhouse gas of greatest concern because it is being released in massive quantities as humans burn fossil fuels. Reducing carbon dioxide emissions is essential to altering the momentum of climate change.

Maryland must reduce its carbon dioxide emissions by 40% of 2006 levels by 2030 to uphold its commitment to the principles of the Paris Climate Agreement. In considering this challenge for Maryland, we must remember that Maryland is not acting in isolation. Acting alone, Maryland could reduce its carbon emissions by 100% but make no difference in the outcome for our world climate.

The citizens of Maryland, along with the citizens of every other state and nation, face the moral question of whether to contribute to a collective goal and trust that others will do the same. To focus on the costs of Maryland's own efforts while ignoring the international context would be a mistake. Decision makers must realize that Maryland's actions send a message to other governments; whichever direction Maryland takes will be magnified by governments that follow Maryland's lead. If Maryland does not uphold its commitment, other governments will be less likely to uphold theirs, and climate change will intensify. If Maryland shows the world that it can meet or exceed its emission reduction goals, other governments will be more likely to substantially reduce their emissions, and Maryland citizens will benefit.

The challenge facing Maryland is to heavily reduce its carbon dioxide emissions without negatively impacting its economic growth or its residents. Economists are in consensus that the most economically efficient way to reduce carbon emissions is to put a price on carbon (Bhandari, Giacomoni, Wollenberg, & Wilson, 2017; Shmalesee & Stavin, 2017; Aldy, Ley, & Parry, 2008). Currently, most consumers can burn fossil fuels without paying a fee for the carbon dioxide they emit. Thus, consumers and firms have no financial incentive to reduce their carbon emissions. When people have to pay to emit carbon, they will look for ways to lower their costs through reducing carbon emissions. They will innovate to increase energy efficiency and use lower-carbon or carbon-zero energy sources that minimize their costs. Pricing carbon results in more flexible and creative solutions than a policy that mandates specific methods of carbon reduction, which is why it is more economically efficient.

In this report, I compare a business as usual scenario to three carbon pricing and revenue distribution designs for the state of Maryland. I evaluate policy options based on their environmental impact, economic impact, and political feasibility. The specific criteria applied are:

- Percent reduction in carbon emissions, compared to a 2006 baseline
- Cost of carbon price to businesses and consumers per ton of CO_2 avoided
- Increase in gasoline prices
- Distance drivers would be willing to drive to buy cheaper gasoline out-of-state
- Public support
- Partisan support

The remainder of this report is organized as follows:

- Literature review of carbon pricing designs and how they interact with other policies
- Description of Business As Usual and three carbon pricing options
- Evaluation of each option according to the six criteria
- Outcomes Matrix that summarizes how each option measures up for all criteria
- Recommendation of Expanding Cap and Trade
- Implementation section with suggestions for building a successful coalition of support

LITERATURE REVIEW

Carbon pricing designs and choices about revenue spending each have strengths and weaknesses. The mix of other greenhouse gas policies already in place in Maryland impacts the efficacy of adding in a new carbon emissions policy. In this literature review, I explain the difference between carbon cap and trade[1] and a carbon tax. In this report, I use the terms "carbon fee" and "carbon tax" interchangeably. Public response to "carbon fee" is more favorable than to "carbon tax" (D. Breslow, personal communication, March 16, 2018). I also use the terms "carbon dioxide," "carbon," and "CO_2" interchangeably. I describe the major carbon reduction programs already enacted in Maryland and explain how carbon reduction policies can unintentionally interact with each other to reduce efficacy and raise costs.

A PRICE ON CARBON

When people have to pay to emit carbon dioxide, fuels that emit more CO_2 per unit of energy incur steeper fees than those that are less carbon-intensive. Table 2 shows the relative carbon intensity for selected energy sources. A price can be put on carbon dioxide either through a carbon tax or through a carbon allowance market, also known as "cap and trade." The main distinction between a carbon tax and cap-and-trade is where the uncertainty lies. With cap-and-trade, carbon emissions are limited to a set amount, while the price of allowances is uncertain. With a carbon tax, the price is known, but the amount of carbon emissions is uncertain. While environmentalists prefer knowing that emissions will decrease over time through lowering the cap, business owners prefer knowing what the price of carbon will be in the future so they can make long-term plans accordingly (Aldy, Ley, & Parry, 2008).

Carbon dioxide emissions impose a cost on society through storm damage, crop loss, and health problems exacerbated by climate change. That cost is called the social cost of carbon. Under the Obama Administration, the Environmental Protection Agency (EPA) calculated the social cost of carbon in 2018 to be approximately $40/ton of CO_2 (EPA, 2017). Economists have a wide range of estimates of the social cost of carbon and acknowledge a high degree of uncertainty about its actual value (Pindyck, 2013). While a maximally efficient carbon fee per ton of carbon dioxide would equal the social cost of carbon**, a carbon fee can still effectively lower carbon emissions without perfect knowledge of carbon's cost to society.** A carbon price could cover some or all of Maryland's carbon sources.

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[1] See the glossary for definitions of this and other terms in this report.

Table 2: Relative Carbon Dioxide Emissions From Selected Fuel Types

A higher number results in a larger carbon fee per BTU of fuel.

Fuel Type	Kilograms of CO2 Emitted Per British Thermal Unit (kgCO2/BTU)
Solar	0
Natural Gas	53
Gasoline	71
Coal (average of all types)	93

Source: Effects of carbon tax on specific fuels, by Resources for the Future
Note: 1000 kilograms = 1 metric ton.
BTU = British Thermal Unit

Most of the literature about carbon taxes focuses on national-level policy. More research is needed at the state level. British Columbia (BC), which began a revenue-neutral carbon tax in 2008, is a useful source of data about the efficacy of a sub-national-level carbon tax. Because British Columbia does not have other carbon-reduction policies, statisticians can more accurately measure the impact of the tax policy in isolation. Researchers estimated that BC's carbon emissions have decreased between 5 and 15% since 2008 (Murray & Rivers, 2015). The carbon tax appears to have no significant impact on BC's economy overall. The literature lacks research on the effect of BC's carbon tax outside of the province.

Several experts stressed that a **good carbon tax design is transparent**. If a government claims that its carbon tax is revenue-neutral, it needs to demonstrate to the public that the tax is in fact revenue-neutral every year (Murray & Rivers, 2015; Sumner, Bird, & Dobos, 2011; Sorrel & Sijm, 2003). A public report of revenue generated, method of distribution, and the corresponding reduction in revenue from other taxes is essential to building public trust.

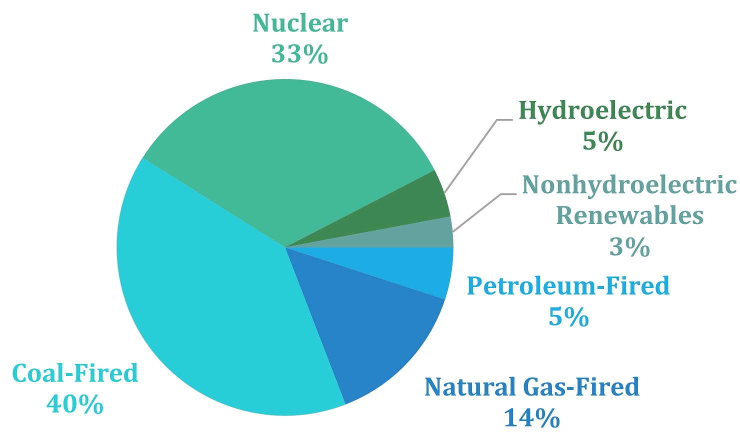
INTERACTIONS OF MULTIPLE CARBON REDUCTION POLICIES

Unlike British Columbia, Maryland already has some carbon-reducing policies in place. The three policies with the largest effect are 1) a carbon cap-and-trade market for power plants, 2) a renewable energy portfolio standard (RPS), and 3) standards for vehicle fuel efficiency that exceed national standards. These policies are not necessarily additive; **more policies may not lead to further emission reductions but could add unnecessary expense.** Adding a carbon price into this mix requires careful design and understanding of how policies interact with one another.

REGIONAL GREENHOUSE GAS INITIATIVE

Maryland is a member of the Regional Greenhouse Gas Initiative (RGGI, pronounced "Reggie"), a coalition of nine (soon to be 10) northeastern states that require their large power plants to purchase allowances to emit carbon. Since RGGI began in 2009, it has **caused a 19% reduction in carbon emissions** from power plants in RGGI states (Murray & Maniloff, 2015). See Appendix A for details about RGGI. Figure 1 shows Maryland's current portfolio of electricity sources.

Figure 1: Maryland Electricity Generation



Source: Maryland State Profile and Energy Estimates, EIA (2018)
Note: Maryland imports most of its renewable energy from other states (Maryland State Archives, 2017). This pie chart covers only in-state generation.

RENEWABLE ENERGY PORTFOLIO STANDARD

Maryland's renewable energy portfolio standard requires 25% of electricity to be produced by renewable energy by 2020 (Marcy, 2017). Because the private market tends to underinvest in the research and development of renewable energy, RPS policies can serve as a method for jump-starting investments in renewable energy (Sorrell & Sijm, 2003). Once renewable energy generators overcome initial barriers to market entry, the usefulness of an RPS diminishes. An RPS can be an expensive way to increase cuts in carbon emissions. The strength of a carbon tax is that it induces the private market to find the most cost-effective way to reduce emissions. An RPS dictates how emissions should be reduced (for example, through solar energy, instead of through energy efficiency), and can force electric utilities to invest in costly options, while cheaper clean options are left underused.

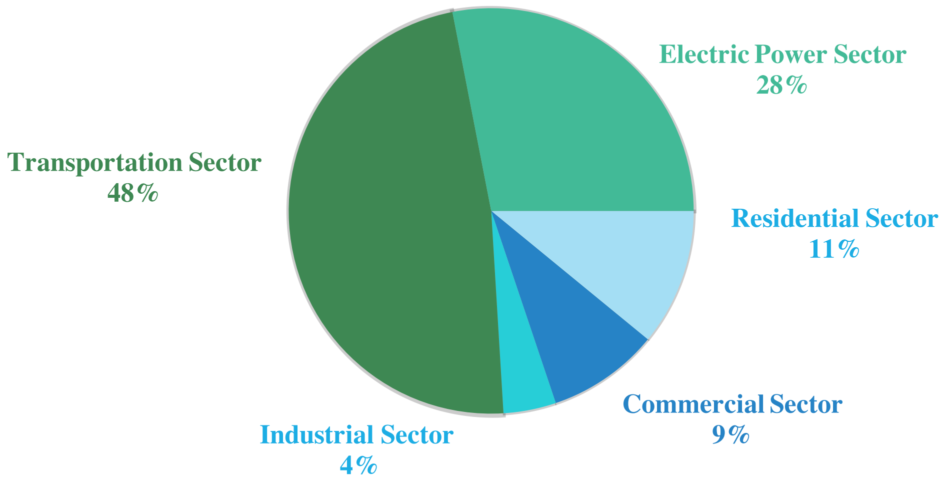
Compared to either an RPS or a carbon market used alone, the combination of an RPS together with cap and trade raises energy prices and increases the use of the dirtiest fossil fuels (Böhringer & Rosendahl, 2010).

Initially, the RPS raises the production of renewable energy above the level it would be at under cap and trade alone. Though this seems beneficial, the second effect is to reduce demand for the carbon allowances. Because demand is low, carbon allowances can be bought for cheap. Coal-fired power plants can then afford to purchase the artificially cheap allowances and produce more coal-based electricity than they would have if allowances were more expensive (Sorrell & Sijm, 2003). **If Maryland combines an RPS with a cap that covers out-of-state generation, carbon emissions would not be further reduced and electricity costs would increase**. As Maryland considers how to shift away from a carbon-based economy, decision-makers should examine whether to eliminate its RPS.

CLEAN CARS PROGRAM

As Figure 2 shows on the next page, transportation emits more CO_2 than any other sector in Maryland. The Clean Cars Program in Maryland requires higher fuel efficiency standards than the national standard (Maryland Department of the Environment, 2013). National standards for fuel efficiency are for the national average for all the vehicles sold per year by each car company. Higher standards in one or two states do not reduce overall national carbon emissions from vehicles. Instead, they shift the sales of lower-emitting vehicles to the more stringent states, while less fuel-efficient vehicles are sold in higher numbers in other states (Goulder & Stavins, 2011). **Eliminating the carbon standard from the Clean Cars Program and instead imposing a carbon price on gasoline and diesel fuels in Maryland may be a more effective way to achieve *national* emission reductions**. At the very least, policy designers should examine how a carbon tax would interact with the Clean Cars Program. Table 3 summarizes the carbon policies discussed so far.

Figure 2: Maryland Carbon Emissions From Major Sectors In 2015



Source: Energy Information Administration (EIA) State Carbon Dioxide Emissions Data (2017)
Note: Maryland emitted 59.4 million metric tons of CO2 in 2015

Nationally, 60% of emissions from the transportation sector are from light-duty vehicles and 23% from medium- and heavy-duty trucks. The remaining emissions are from boats, trains, airplanes and miscellaneous other modes of transport (EPA Office of Transportation and Air Quality, 2017).

Table 3: Summary of Carbon Policy Definitions, Strengths, and Weaknesses

Policy	Definition	Strength	Weakness
Renewable Energy Portfolio Standard (RPS)	Electricity utilities are required to produce a certain percent of electricity using renewable energy	Increases demand for renewable energy. Promotes new development of renewable energy, leading to lower costs through economies of scale. Useful for jump-starting renewable energy industry.	Top-down government control of electricity industry in what is otherwise designed to be a free market. Increases cost of electricity by it forcing utilities to purchase electricity from more expensive sources. In combination with a carbon price, it does not create further reductions in CO2 emissions.
Carbon Fee (also known as Carbon Tax)	For every metric ton of CO_2 ($mtCO_2$) emitted, emitters must pay a set fee to the government. Fee starts low and increases over time.	A price on carbon makes carbon-emitting energy sources more expensive. This evens the playing field for carbon-free energy and efficiency. Businesses can plan ahead for increasing carbon fee.	Does not guarantee lower carbon emissions. When economy is strong, people are willing to pay a lot to emit a lot carbon. If not revenue-neutral, will increase government spending
Carbon Cap and Trade	The government sets a limit, or cap, on total carbon emissions. The cap is lowered annually. Allowances to emit 1 ton of CO_2 are sold through an auction. Allowances can be used or sold.	Creates certainty in carbon emission reductions. As the cap is lowered, the allowance price increases, creating greater incentive to use less carbon-intensive energy sources. Evens playing field for carbon-free energy and energy efficiency.	Businesses cannot plan their long-term budget, because the future price of carbon allowances is uncertain. If not revenue-neutral, will increase government spending.
Clean Cars Program	Requires higher fuel efficiency standards for vehicles purchased in Maryland	Sends signal that a market exists for fuel-efficient vehicles. If enough states adopt the standards, it could increase the average fuel efficiency of the national fleet of vehicles.	In combination with national CAFE fuel efficiency standards, does not increase the average fuel efficiency of all American vehicles. Instead, it shifts more sales of fuel-inefficient vehicles into other states.

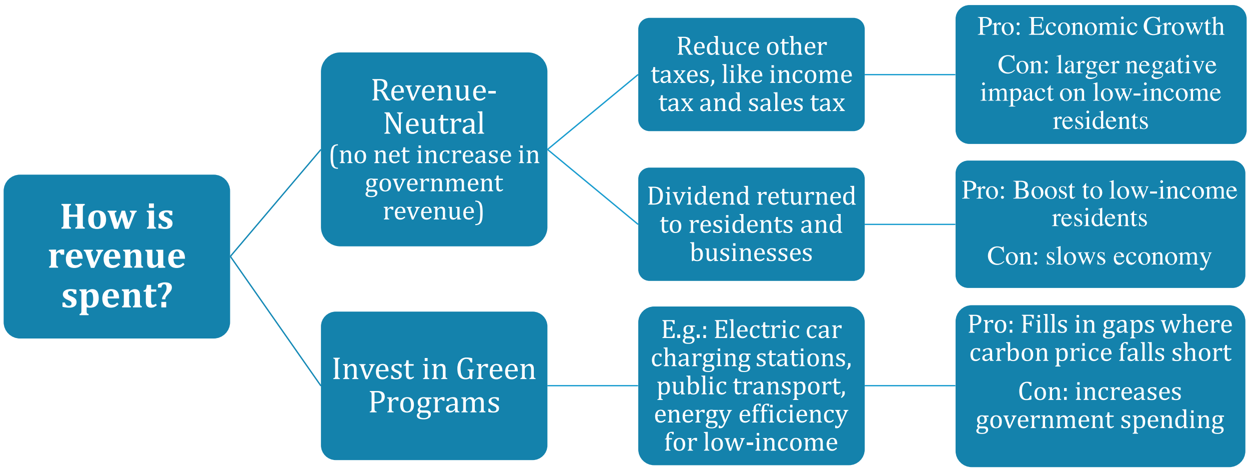
REVENUE SPENDING OPTIONS

Carbon pricing generates revenue, which leads to a second set of decisions: how to spend the millions of dollars in new state revenue. Though the money could be spent on any item in the state budget, I limit my discussion to options that could further reduce carbon emissions, strengthen the economy, and/or lessen the financial burden for low-income households.

A carbon fee designed to be revenue-neutral could be more politically palatable than one that increases state spending (Carbone, Morgenstern, Williams, & Burtraw, 2013). Revenue neutrality could be achieved through reducing capital taxes, reducing labor taxes, reducing consumption taxes, or a combination of all three. Alternatively, revenue neutrality can be reached through returning a flat rebate to all tax payers. A flat rebate, referred to as "fee and dividend," places the least burden on low-income members of society. A fee-and-dividend model also reduces Gross Domestic Product (GDP) (Carbone, et al., 2013). A revenue-neutral tax achieved through cuts in capital taxes slightly *increases* GDP. Because low-income households spend a larger percent of their budget on energy than higher-income households, a carbon tax will impact low-income households more. Yet if revenue from a carbon tax is used exclusively to counteract the regressive effect of the tax, it could create a drag on the GDP. This trade-off is essential to consider when designing a state-level carbon tax (Morris, Bauman, & Bookbinder, 2016).

A different option for revenue use is to spend it on programs that further reduce greenhouse gas emissions. For the most part, designating revenue from carbon pricing on "green programs" that further promote renewable energy is not necessary or cost effective (W. Shobe, personal communication, March 13, 2018). For example, some environmentalists advocate for revenue spending on research and development of renewable energy. This spending restriction is unnecessary because the carbon price will create the incentive for private industry to conduct their own research and development. Carbon pricing does not solve all carbon emissions problems, so revenue can be used to fund "complementary policies" that fill in the gaps where carbon pricing falls short. For example, carbon pricing motivates people to use public transportation, but they cannot use what does not exist. Revenue can be used to expand public transportation. Likewise, higher energy prices motivate people to improve their energy efficiency. Revenue can fund grants to low-income households that cannot afford the upfront costs of energy efficiency upgrades. Figure 3 summarizes the options for distributing revenue from a carbon pricing policy.

Figure 3: A Decision Tree of How to Spend Revenue from A Carbon Fee or Carbon



FINDING THE BALANCE

Carbon pricing is intended to cause enough financial impact on people that they change their behavior. Financial impact equates to financial struggle for low-income households. Fortunately, wise distribution of the revenue from a carbon price can offset the extra cost of carbon for low-income households while keeping the overall economy strong. Our concern for people living in poverty must not prevent us from pricing carbon. If we do not take bold action to reduce carbon emissions, climate change will disproportionately hurt people already living in poverty.

By the end of this century, if present trends in greenhouse gas emissions continue, the poorest decile of counties[2] in the United States will likely suffer 11% of the nation's economic damage from climate change. Meanwhile, the richest decile of counties will suffer just 2% of the national costs of climate change (Hsiang, et al., 2017). Acting to reduce carbon emissions will negatively impact some people. Refusing to reduce carbon emissions will cause far greater devastation, especially for people already under financial strain.

[2]Based on average income level

MAIN POINTS

- A carbon fee or expanded cap and trade can further reduce carbon emissions in Maryland if it is designed with Maryland's other emission reduction policies in mind.
- The carbon price should be used to cover sources of carbon that are not currently regulated by other policies. Where those other policies exist, Maryland needs to examine whether those policies should be replaced by the carbon price.
- If a carbon price is added to current policies, it may not provide additional emissions reductions. It may increase costs to society with no added benefits.
- If complementary policies are instead used to address specific market failures created through pricing carbon, they may truly work together to decrease emissions.
- When designing a revenue-neutral carbon fee, consider the trade-off of allocating revenue to either promote growth of the GDP or to reduce the disproportionate burden of a carbon price on low-income members of society.

POLICY OPTIONS ANALYZED

I compare four policy options for achieving the goal of reducing carbon emissions by 40% by 2030. I list these options here and then describe them in further detail below.

Option 1: Business As Usual

Option 2: Slow-Growth Fee and Dividend:
Start at $15/ mt$CO_2$, Increase by $5/year until $45/mt$CO_2$

Option 3: Fast-Growth Fee and Dividend
Start at $15/ mt$CO_2$, Increase by $10/year until $145/ mt$CO_2$

Option 4: Expand Cap and Trade
Leave RGGI and link with California, Ontario, and Quebec's Cap and Trade

OPTION 1: BUSINESS AS USUAL

My Business As Usual (BAU) option assumes that all of Maryland's current programs are maintained, and includes programs currently scheduled to begin or increase in stringency in the future.

OPTION 2: SLOW-GROWTH CARBON FEE AND DIVIDEND

*STARTING AT **$15**/MTCO2 AND INCREASING BY **$5**/YEAR UNTIL LEVELING OUT AT **$45**/MTCO2*

A carbon fee would be collected per ton of carbon dioxide emitted. It would be levied as upstream in the sale of fuels as possible for administrative ease. Fuels that emit more carbon dioxide per unit of energy would incur steeper fees than those that are less carbon-intensive. This alternative follows the proposed Regional Carbon Cost Collection Initiative (RCCCI, pronounced "Ricky") ("RCCCI," 2018). Appendix B describes RCCCI in further detail.

The revenue generated by the carbon fee would be distributed as follows:

- **67.5% of would be rebated to households**, with a larger rebate to households with income in the bottom 40%.
- **22.5% of would be rebated to employers** who would be at a substantial disadvantage when competing with out-of-state employers due to the carbon fee. This category would also include non-profit organizations and government entities.
- **10% for a "Green Infrastructure Fund"** that would be used to invest in projects that lower greenhouse gas emissions and increase climate resiliency, with a priority on low-income communities.

OPTION 3: FAST-GROWTH CARBON FEE AND DIVIDEND

*STARTING AT **$15**/MTCO2 AND INCREASING BY **$10**/YEAR UNTIL LEVELING OUT AT **$145**/MTCO2*

This alternative would distribute revenue in the same proportions as alternative 2. Option 3 is based on the carbon tax and dividend that CCAN is campaigning for in Washington, DC called "The Climate and Community Reinvestment Act of DC" ("The Climate and Community . . . , 2017). I chose to analyze this option for two reasons. First, increasing the carbon fee by only $5 a year does not reach the goal of 40% emissions reductions by 2030. Second, Maryland and DC's economies are tightly intertwined. The jurisdictions will be better able to reduce overall carbon emissions if they coordinate their policies.

OPTION 4: EXPAND CAP AND TRADE:

*LEAVE RGGI AND **LINK WITH CALIFORNIA**, ONTARIO, AND QUÉBEC'S CAP AND TRADE PROGRAM*

RGGI is a cap and trade program that covers only large power plants. This cap leaves other major sectors of the economy without stringent carbon regulations. Because RGGI states work through unanimous consensus on RGGI policy, Maryland cannot expand its cap to cover other carbon-emitting sectors unless all RGGI states agree. Persuading other RGGI states to put more carbon emitting sources under the cap would take time. A quicker solution for Maryland would be to link with California's carbon cap-and-trade program (AB 32), which already covers all fossil fuels sold in the state, all electricity generated out-of-state using fossil fuels, and other major sources of greenhouse gases ("California Cap and Trade," n. d.) Québec linked their cap and trade program with California's in 2014, and Ontario linked in 2018. Linking allows entities within each jurisdiction to buy and use allowances originating in the other jurisdictions. Linking creates a larger market in which Maryland's entities can buy and sell allowances in a larger market. A larger market results in prices that create the most efficient reduction in carbon at the lowest overall cost to society.

Linking with other states and provinces does not require Maryland to use its revenue in the same way as they do. Under this alternative, Maryland would allocate:

- **50% Dividend** to households, with lower income receiving higher dividends
- **20% Offset lower corporate taxes**
- **30% Complementary projects** that further reduce carbon emissions
    - Grants to low-income households and businesses to improve **energy efficiency**
    - Infrastructure that reduces carbon emissions from **vehicles**

My rationale for this distribution of revenue can be found in the Implementation section. I outline the details of RGGI in Appendix A and the details of California's AB 32 in Appendix C.

EVALUATIVE CRITERIA

I evaluate the four options according to six evaluative criteria, listed below. I describe each criterion, apply it to each option, and summarize how the options measure up at the end of each criterion section. An outcomes matrix displaying the outcomes for all of the options and criteria concludes this section and is the basis of my recommendation.

1. Percent reduction of carbon emissions
2. Cost of expenditures per ton of CO_2 avoided
3. Increase in gasoline prices
4. Distance drivers would be willing to drive to buy cheaper gasoline out-of-state
5. Public support
6. Partisan support

BY HOW MUCH ARE CARBON EMISSIONS REDUCED?

The most important criterion is whether the plan meets the goal of reducing carbon emissions by 40% of 2006 levels by the year 2030. As Table 4 below shows, both the fast growth fee-and dividend option and the expanded cap-and-trade option exceed the goal of a 40% reduction. The slow-growth fee-and-dividend option falls short. Falling short would require additional policies to achieve the 40% reduction goal, which would be less economically efficient than putting a price on carbon. Those additional policies would require their own governmental oversight, increasing the amount of government regulation.

Table 4: Percent Decrease in Carbon Emissions in 2030, Compared to a 2006 Baseline

Business As Usual	Slow-Growth Carbon Fee-and-Dividend	Fast-Growth Carbon Fee-and-Dividend	Expand Cap-and-Trade
22%	33%	41%	47%

Methodology can be found in Appendix D

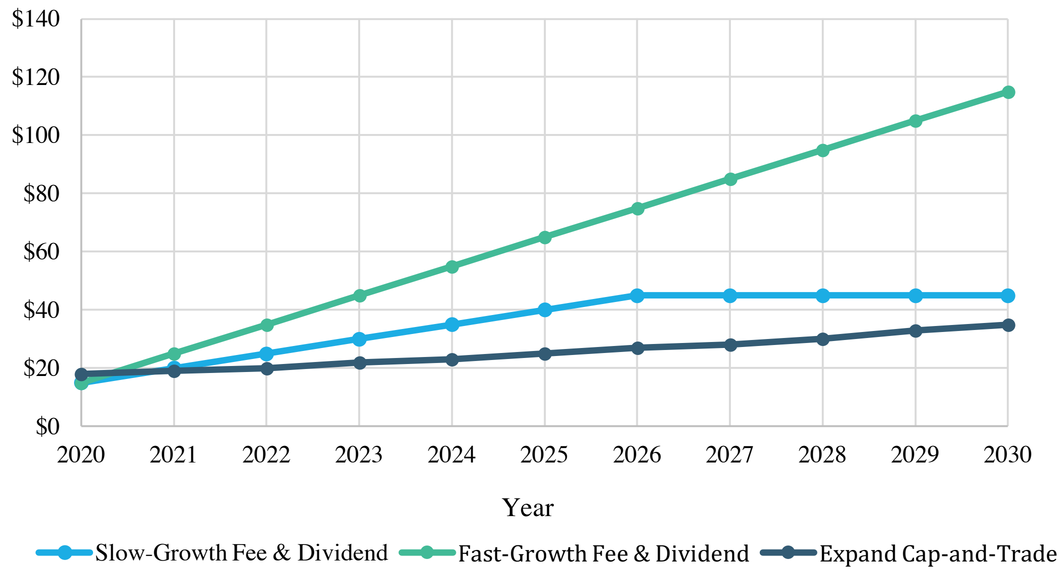
COST OF EXPENDITURES PER TON OF CARBON DIOXIDE AVOIDED

As I elaborate in this section, expanding cap-and-trade is substantially more cost effective than imposing a carbon tax.

COST PER TON OF CARBON AVOIDED

The cost per ton of carbon emitted under each alternative carbon pricing plan is shown in Figure 4. I estimated that the cost of one allowance under an expanded cap-and-trade policy would increase at 7% per year. In Appendix E, I describe my methodology for determining the price of carbon allowances under cap and trade linked with California's AB 32.

Figure 4: Price of One Metric Ton of CO_2 Over Time



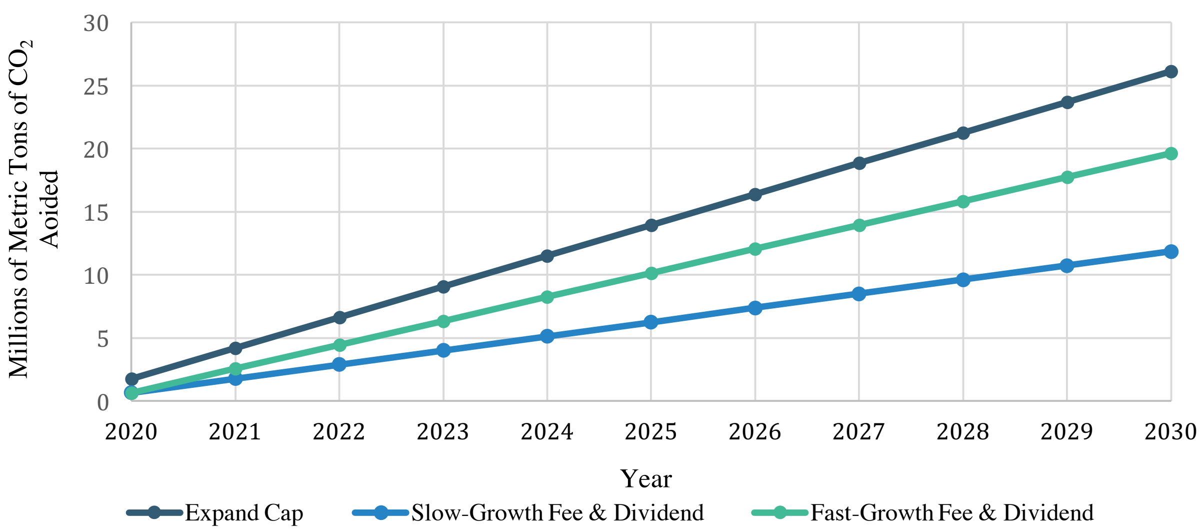
These prices show that **expanding cap and trade will cost *less* per ton of carbon emitted than either a slow-rising or fast-rising carbon fee.** My estimate that allowance prices will increase by 7% a year may be incorrect. In order for allowance prices to be at least $45/mt$CO_2$ in 2030, they would have to increase by 10% every year. As a comparison, allowance prices in California have increased by approximately 5% over the past 3 years (see Appendix E).

A very important question is how much each ton of CO_2 *avoided* costs society. The chart above shows the cost per ton of CO_2 *emitted*. Calculating the cost to society of each ton avoided requires highly sophisticated modeling with a large amount of data input. Unfortunately, such modeling is beyond the scope of this project.

Instead, I designed an alternative way to think about the cost of CO_2 avoided, which I believe is a useful metric. I calculated the **Cost of Expenditure per Ton of CO_2 Avoided**. This metric requires explanation. When economists measure the cost per unit improvement, they technically do not count payment to the government as a "cost to society." Rather, it is a "transfer" from one part of society to the other.

My metric does not consider the society as a whole; it only considers the cost to those who have to pay the carbon price. I assume that people would rather not pay an extra fee on their fossil fuel consumption. Thus, I am considering any payment to the Maryland government for carbon emissions to be an undesired "expenditure." I calculated the total expenditures from 2020 to 2030 under each option. I then calculated the total emissions avoided from 2020 to 2030 under each option compared to emissions under Business As Usual, as shown in Figure 5.

Figure 5: Tons of CO_2 Avoided Per Year
Compared to Business As Usual



Source: Author's calculations, available in Appendix E

To arrive at the **Cost of Expenditures Per Ton of Emissions Avoided**, I divided the total expenditures by the total tons of CO2 avoided. Table 5 shows that the cost of expenditures avoided is much lower under the expanded cap and trade option than under either carbon fee option.

Table 5: Cost of Expenditures Per Ton of CO2 Avoided from 2020 to 2030 (Net Present Value)

	7% Discount Rate	3% Discount Rate
Slow Growth Carbon Fee & Dividend	$480	$460
Fast Growth Carbon Fee & Dividend	$484	$472
Expanded Cap	$143	$104

Methodology can be found in Appendix E

My results show that Maryland residents and businesses would have to *pay over three times as much* to the Maryland government for carbon emissions under a Carbon Fee than under Expanding Cap and Trade for each ton of carbon avoided. Considering this metric alone, Maryland residents would probably prefer to expand cap and trade.

COST TO SOCIETY

Fortunately, the cost to *society* per ton CO_2 avoided is much lower than the cost to consumers and firms of expenditures per ton. The expenditures paid by businesses and consumers becomes revenue for the State of Maryland. The government uses that revenue to benefit society. The dollar value of those benefits could be less than, equal to, or greater than the cost of expenditures forked over to the government. The benefit provided by the revenue depends greatly on how that revenue is spent. If it is spent wisely, the total cost to society of pricing carbon could be very low. I will discuss this topic further in the Implementation section.

THE IMPACT OF A CARBON PRICE ON GASOLINE AND CONSUMER BEHAVIOR

All of the alternatives to Business As Usual include putting a price on carbon emissions from the transportation sector. Because this would be a new cost to driving in Maryland, understanding its impact on consumer behavior is important. First, I calculated the added cost per gallon of gasoline in 2030 under each alternative, as show in Table 6.

Table 6: The Additional Cost of a Gallon of Gasoline in 2030

Business As Usual	Slow-rise Carbon Fee-and-Dividend	Fast-rise Carbon Fee-and-Dividend	Expand Cap-and-Trade
$0	$0.40	$1.02	$0.31

Appendix F contains methodology for these calculations

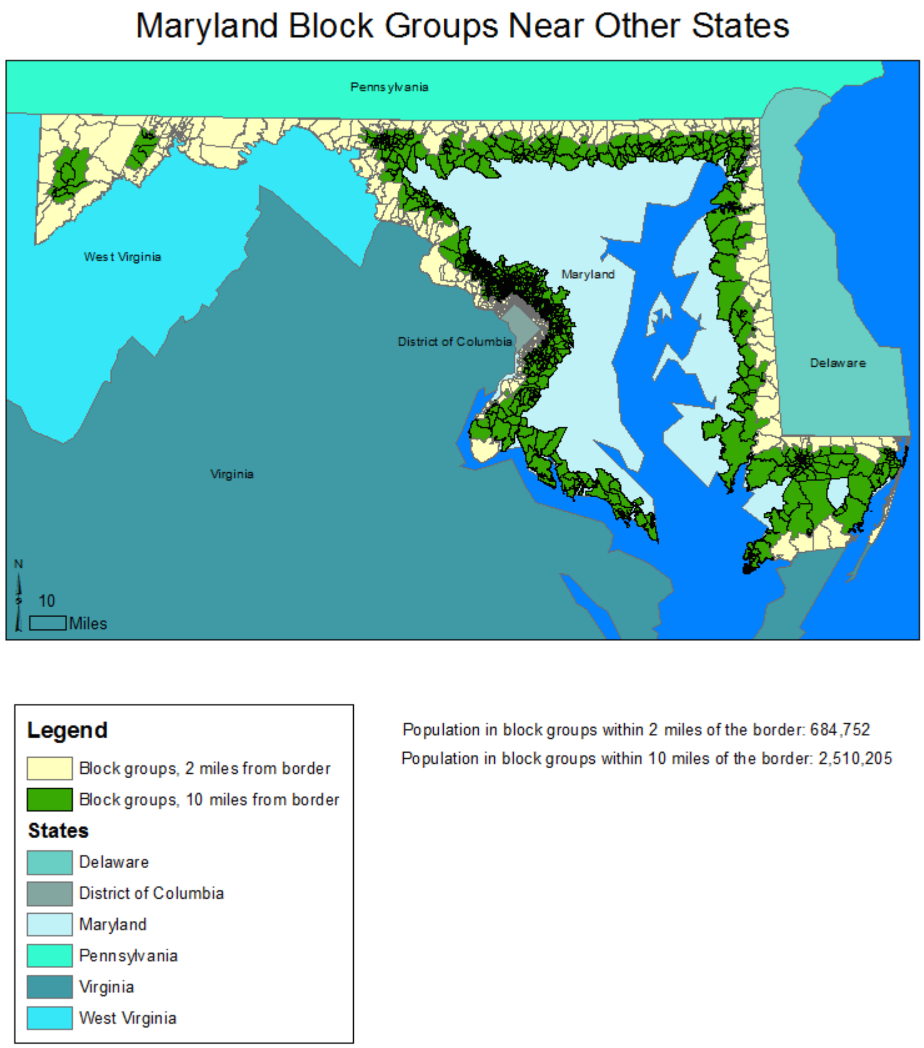
The difference in additional cost per gallon of gasoline under each option raises three essential questions. First, if gas prices in Maryland increase, how far will Maryland drivers be willing to drive to cross the state line to buy cheaper gasoline? Second, will increased gas prices result in reduced carbon emissions from the transportation sector? Third, how will increased gas prices affect consumer-oriented sectors of the Maryland economy?

HOW FAR WILL MARYLAND DRIVERS DRIVE TO BUY CHEAPER GASOLINE?

If a carbon price makes gasoline more expensive in Maryland than in bordering states, will Maryland drivers choose to drive across state lines to fill their gas tanks? If they do, a carbon price could actually result in greater carbon emissions, as people drive extra miles to purchase cheaper gasoline.

Due to Maryland's shape, many Maryland residents live close to the state border. The map in Figure 6 below shows census blocks containing area that is two or less miles from the state line (yellow) or contain area that is 10 miles from the state line (green). This map shows distances "the way the crow flies," not distances along roadways. Naturally, people living in rural areas and along the mouth of the Potomac River have limited road access and indirect driving routes to cross the border. Nevertheless, the map illustrates that many drivers in Maryland live just a few miles from the state line, and have a choice of the jurisdiction in which they purchase their gasoline.

Figure 6: Population census blocks within 2 miles and 10 miles of the Maryland state border



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Source: United States census data mapped by Michael Bacon (2018)

Table 7 shows the distance people would drive to a gas station that does not have the extra cost of a carbon price. These results show that with a substantial carbon tax of **\$115/mtCO_2**, such as in the fast-growth carbon fee scenario in 2030, people would be willing to drive **11.7 miles (23.4 miles round-trip)** to buy cheaper gasoline. Given the distribution of the population in Maryland, this distance would be within range for many drivers. In 2030, under the **slow-growth carbon fee** option, people would be willing to drive **4.5 miles** to avoid the additional cost of \$0.40/gallon. Under the **expanded cap-and-trade option**, people would be willing to drive only **3.5 miles** to buy cheaper gasoline.

Table 7: Distance consumers are willing to drive to avoid a carbon tax on gasoline: 1-way distance to gasoline station in miles

Year	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Slow-growth carbon fee	1.6	2.2	2.7	3.2	3.7	4.2	4.7	4.7	4.6	4.6	4.6
Fast-growth carbon fee	1.6	2.7	3.8	4.8	5.8	6.8	7.8	8.8	9.8	10.7	11.7
Expand cap & trade	1.9	2.0	2.2	2.3	2.5	2.6	2.8	2.9	3.1	3.3	3.5

Appendix G contains methodology for these calculations

IMPLICATIONS FOR CARBON PRICING POLICY

Because thousands of Maryland residents commute to Washington, DC and Northern Virginia, coordinating a carbon price with neighboring states, and with DC in particular would strengthen Maryland's carbon policy. RCCCI, upon which the slow-growth carbon fee is based, stipulated that the carbon fee would go into effect only when two or more bordering jurisdictions or RGGI member states also implement a similar carbon price. This trigger would improve Maryland's carbon price in two ways. First, if a bordering state implements a carbon price, it would reduce the negative impact of people driving out of state to purchase gasoline and other fossil-fuel intensive products. Second, the trigger would amplify Maryland's impact on carbon emissions, by encouraging other states to further reduce their emissions.

EFFECT OF CARBON PRICING ON CONSUMER BEHAVIOR

The purpose of adding a carbon price to gasoline is to motivate people to use less gasoline. Gasoline prices already fluctuate for a variety of reasons, allowing us to examine whether higher gas prices really do decrease miles driven. Unfortunately for the fight against climate change**, higher gas prices do not result in people driving substantially less, at least in the short term** (Morris, 2014). Factors influencing the lack of response to higher gas prices include:

- Inability to quickly change one's commute distance
- Inability to make one's vehicles more fuel efficient until purchasing a new vehicle
- Alternatives to driving are not available
- Alternatives to driving are not desirable

When gasoline is more expensive, people spend more of their budget on gasoline. This leaves less of their budget for other purchases. Farrell and Grieg (2015) studied the purchasing habits of 25 million credit card holders as gasoline prices dropped 45% over an eight-month period. When gasoline prices dropped, people did not buy more gasoline, but consumers spent 80% of their savings at the pump on goods and services. They spent 18% on restaurants, 7% on entertainment, and 33% on non-durable goods such as groceries and items from department stores. These results imply that the opposite effect would occur when gas prices increase. Restaurants, retail stores, and the entertainment industry would lose money. This impact is important to consider; some carbon price policy designers are concerned with providing a level of protection to industry and commercial sectors that are energy intensive (for example, Breslow & Pickens, 2018). However, other industries that are not energy intensive could feel the brunt of a carbon price indirectly, because they are offering non-essential goods and services.

The ripple effect of a carbon price throughout the Maryland economy provides an imperative to design a carbon policy that reduces gasoline consumption, so that sectors reliant on discretionary income do not lose business.

The fact that higher gas prices do not substantively reduce driving should not deter us from putting a price on carbon emissions from gasoline. The price sends a signal to consumers, and consumers will respond. If they do not respond in the way intended, we must remove the barriers to consuming less gasoline. If public transport is unavailable or undesirable, some of the revenue that Maryland collects from pricing carbon can be spent on improving public transportation. Revenue can also be spent on building infrastructure to support electric vehicles. These policies will be discussed further in the Implementation section.

PUBLIC AND PARTISAN SUPPORT

In addition to the environmental and economic impact of each option, I also examined the feasibility of passing a bill to implement the policy. The feasibility depends largely on public support and also on partisan politics. I discuss both in this section.

PUBLIC SUPPORT

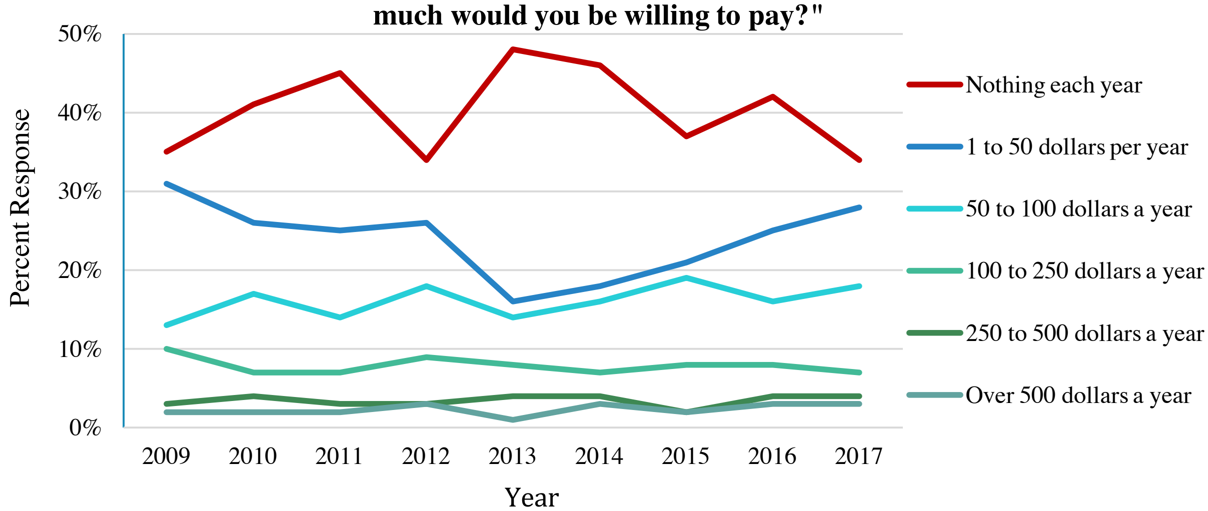
Seventy-seven percent of Maryland residents surveyed said that climate change is a somewhat serious or very serious problem (margin of error = ±8.5%) ("Sierra Club RGGI Survey," 2016). Sixty-six percent of Americans agreed that if the federal government fails to address climate change, it is their state's responsibility to do so (National Surveys on Energy and the Environment, 2017). [3]

In spite of concern about climate change, the Figure 7 shows that **the majority of Americans are willing to pay no more than $50 extra a year** to have more renewable energy produced, with approximately 40% of respondents willing to pay nothing. The chart also shows that **willingness to pay has shown no discernable pattern of change over the past eight years**. It is trending flat. A carbon policy that people perceive to cost them little to nothing will receive much more public support than a policy that is perceived to cost individuals more than $50/year. Even if a policy is cost-neutral for an individual, people must be able to perceive it as such in order to support it.

If a price on carbon increased gasoline prices by 8¢ per gallon, only 38% of those surveyed would support it (NSEE, 2016). If a carbon price increased gasoline costs by 42¢ per gallon, support drops to 28%. Eight cents per gallon is equivalent a $10/mtCO_2$ fee. Forty-two cents per gallon is equivalent to a $50/mtCO_2$ fee (Hafstead & Picciano, 2017).

[3] The number of Maryland residents in this annual survey was less than 30, making the sample size from Maryland too small to apply to the general population of the state.

Figure 7: Responses to the Survey Questions: "If it required you to pay extra money each year in order for more renewable energy to be produced, how much would you be willing to pay?"



Source: National Surveys on Energy and the Environment (NSEE).
Sample size is 837-939, depending on year. Margin of Error is ±3.5%.

MAIN POINTS:

- Most Americans are concerned about climate change.
- Most Americans believe that states should address climate change if the federal government does not.
- Approximately 40% of Americans are not willing to spend any money to increase the use of renewable energy.
- Support is low for higher gasoline prices caused by a carbon price.

CARBON FEE AND DIVIDEND

In the United States, public support for a carbon fee has increased in recent years. Fifty percent of those surveyed in 2016 support a carbon tax, up from just 36% in 2009 (Rabe & Mills, 2017). This support held steady even if the tax meant that the participant's energy costs increased by 10% (NSEE, 2016). Support increased to 62% if all of the tax revenue were returned to the public as an income tax rebate.

Support for a carbon tax is much higher among Democrats that among Republicans. Sixty-six percent of Democrats, compared to only 30% of Republicans, supported a carbon tax in 2015 (Rabe & Mills, 2017).

MAIN POINTS:

- Support for a carbon tax is increasing.
- People are more favorable of a revenue-neutral carbon tax that reduces their income tax.
- Support for a carbon tax is highly partisan, with most Democrats supporting it.

EXPAND CAP AND TRADE

Nationally, **support for cap and trade has decreased** since 2009. In 2015, 31% of those surveyed supported cap and trade, down from 54% in 2009 (Rabe & Mills, 2017). Thirty-five percent opposed it. Survey results showed **no statistically significant difference between Democrats and Republicans in support of or opposition to cap and trade.**

When given further information about how the revenue from cap and trade would be spent, public support for it increased. Forty-seven percent of Americans support cap and trade if the revenue is used to increase energy efficiency to reduce household electricity use. Forty-one support the use of cap-and-trade revenue if it is used entirely to offset other taxes. Notably, a **quarter** of respondents in both cases of revenue spending are **not sure** whether they would support the cap-and-trade policy. This represents both a challenge and an opportunity. Much of the public needs further education about cap and trade in order to make up their minds, but this also means that much of the public may come to support cap and trade once it becomes more familiar.

Within Maryland, support for the RGGI cap-and-trade program is high. In a survey of 203 Maryland residents, 81% supported doubling the rate at which the cap is lowered, from 2.5% per year to 5% per year (margin of error = ±8.5%) ("Sierra Club RGGI Survey," 2016). People's support for RGGI seems easily swayed. After hearing arguments for and against RGGI, the percent of respondents supporting RGGI dropped to 71%. Because the sample size was low, the actual percent of Maryland residents who could easily change their mind about RGGI may be quite lower or higher than these survey results. Given the broad support for RGGI and for lowering its cap at a higher rate, **the majority of Maryland residents are likely to favor expanding cap- and trade** beyond the power sector. As with initiating a carbon fee, support for expanding cap and trade will **depend heavily on whether the program is perceived to be low-cost to no-cost for consumers.**

MAIN POINTS:

- Support for cap and trade has decreased since 2009.
- Support for cap and trade is non-partisan.
- A quarter of Americans are undecided about their opinion of cap and trade.
- Support in Maryland is high for making RGGI more stringent.

POLITICAL FEASIBILITY

Fifty-five percent of adults in Maryland are Democrats or leaning Democrats, and 31% are Republicans or leaning Republicans (margin of error = ±5%) ("Party affiliation among adults in Maryland," 2015). **Given the partisan basis of support for a carbon tax, the total support for a carbon tax in Maryland is likely to be higher than at the national level**.

Maryland's Governor Larry Hogan is a Republican who supports some climate change mitigation actions. In 2016, he signed the Greenhouse Gas Reduction Act bill that set the goal of reducing Maryland's greenhouse gas emissions by 40% by 2030 (Office of Governor Larry Hogan, 2016).

Of Maryland's 47 state senators, 32 are Democrats ("Maryland General Assembly," 2018). Of Maryland's 141 state delegates, 91 are Democrats. **These numbers in both houses give Democrats the 3/5 voting block to override a veto by Governor Hogan**. In February of 2017, the Maryland General Assembly successfully voted to override Governor Hogan's veto of a bill that increased Maryland's Renewable Portfolio Standard to 25% by 2020 (Wood, 2017).

During the 2018 General Assembly, the Maryland House Economic Matters Committee considered House Bill 939, the Regional Carbon Cost Containment Act. RCCCI followed the same specifications as the slow-growth carbon fee and dividend option in this analysis. Of the 21 committee members, only two voted in favor of the bill, and it did not move out of committee (Waters, 2018). The Maryland League of Conservation Voters (LCV) publishes an annual scorecard of members of the Maryland General Assembly, based on their voting record on environmental bills. They gave high scores to 13 out of the 21 committee members (Maryland LCV, 2017). Given time to understand the RCCCI bill and the nature of carbon pricing, many of these members could come around to support a carbon pricing bill.

The Democratic majority in the state of Maryland and in the State General Assembly provide a favorable environment for passing a bill placing a price on carbon. The main hurdle is lack of familiarity with how carbon pricing works and how the revenue would be allocated.

Combining all of the information in this section of analysis, **the most politically feasible option would be Business As Usual, followed by the Slow-Growth Carbon Fee and Dividend.** Smaller changes are easier to pass than larger changes. A carbon fee has broader public support than cap and trade. Public opinion does not currently tolerate the higher gasoline price or energy price of the Fast-Growth Carbon Fee and Dividend. **Regardless of the plan implemented, public support depends on the impression that it is cost-neutral or close to for the individual**. Table 8 summarizes the political feasibility of the four options. The Outcomes Matrix on the next page includes analysis of all the criteria for the four options.

Table 8: Political Feasibility of Each Option

	Business As Usual	Slow-Growth Carbon Fee and Dividend	Fast-Growth Carbon Fee and Dividend	Expand Cap and Trade
Ranking of public support for this plan	Highest	Second Highest	Lowest	Second Lowest
Partisan support	More Republican than Democrat support	Majority of Democrats support this plan, and Minority of Republicans	More Democrats support this plan than Republicans	No partisan difference

OUTCOMES MATRIX

Table 9: Summary of Analysis of the Criteria for All Options

	Criteria	Business As Usual	Slow-rise Carbon Fee-and-Dividend	Fast-rise Carbon Fee-and-Dividend	Expand Cap-and-Trade
Environmental	Percent carbon dioxide emissions lowered in 2030 (2006 Baseline)	22%	33%	41%	47%
Economic	Cost of Expenditures per ton of CO_2 avoided (Net Present Value at 7% discount rate, compared to BAU) (lower is better)	N/A	\$480	\$484	\$143
	Additional cost of gallon of gasoline in 2030	\$0	\$0.40	\$1.02	\$0.31
	Miles people are willing to drive to avoid the carbon fee on gasoline in 2030 (lower is better)	0	4.6	11.7	3.5
Feasibility	Rank of public support for this plan	Highest	Second Highest	Lowest	Second Lowest
	Partisan support	More Republican than Democrat support	Majority of Democrats support this plan, and Minority of Republicans	More Democrats support this plan than Republicans	No partisan difference

RECOMMENDATION: EXPAND CAP AND TRADE

Based on the criteria in the matrix above, **I recommend that CCAN promote the Expansion of Carbon Cap and Trade.** This option would require Maryland to withdraw from RGGI, which caps carbon emissions only from large power plants. Maryland would then link their carbon market with California, Ontario, and Quebec. Maryland would follow California's model of capping carbon emissions from power plants, major industry, concrete producers, and all fuels. Expanding cap and trade scores the highest on both economic and environmental impact, but the lowest on political feasibility. No doubt, it would be the most challenging option for CCAN campaign for. **The extra challenge would be worthwhile because expanding cap and trade would produce the greatest reduction in carbon emissions at the lowest cost to consumers.** Regardless of the many worthwhile ways to spend revenue, the method that collects the least revenue will have the smallest negative impact on the state economy and on personal budgets.

At 47%, expanding cap and trade would create the largest reduction in emissions, well exceeding the 40% goal for 2030. Exceeding the goal improves environmental outcomes and also leaves room for error in predictions. For example, the BAU projection and the Fee-and Dividend projections are based on the assumption that EPA's Clean Power Plan moves forward. The Trump Administration is working to dismantle the Clean Power Plan, so the three options based on that assumption may be overly optimistic about how much Maryland will lower is carbon emissions (Friedman & Plumber, 2017). The emissions projected under the Expand Cap-and-Trade option do not depend on implementing the Clean Power Plan.

POSITIVE OUTCOMES OF A CCAN CAMPAIGN TO EXPAND CAP AND TRADE

The purpose of environmental advocacy groups is to influence public opinion and political will. Every alternative examined would require a campaign to build public and political support. Expanding cap and trade would require the largest campaign. CCAN has a track record of pushing for stronger environmental policy that will improve outcomes rather than just give lip service to climate change ("Mission," 2018). As a leader in campaigning for substantial carbon emission reductions in Maryland, CCAN is the right organization to promote an expansion of cap and trade.

A campaign to expand cap and trade could have a few successful outcomes. One is that Maryland leaves RGGI, expands its cap, and links with California, Ontario, and Quebec's carbon markets. Under this outcome, Maryland would achieve its goal of reducing its carbon emissions by 40%. It would also send a very strong message to the rest of the RGGI states, not to mention the rest of the world, that **limiting emissions from the power sector alone is no longer sufficiently ambitious.** An alternatively successful outcome of campaigning to leave RGGI is that other RGGI states would begin serious discussion of expanding the RGGI cap beyond the power sector. Maryland could then stay with RGGI and influence all of the RGGI states to expand their cap collectively. A third possible positive result is that CCAN's campaign to expand cap and trade would push decision makers to take stronger action on reducing carbon emissions than they otherwise would. Under this scenario, Maryland may not expand the coverage of its cap, but it may implement a carbon fee that is more ambitious than it otherwise would have been.

IMPLEMENTATION

Building a coalition broad enough to garner political support to pass a bill expanding cap and trade will take a lot of work and strategy. Two areas of focus deserve extra attention when developing this campaign: educating environmental advocates about cap and trade, and building alliances with members of the Republican Party. CCAN will also need to advocate for the most beneficial distribution of revenue. Regardless of how well the plan is designed, CCAN will need to compromise to gain support of some stakeholders and politicians. My implementation plan includes a section recommending which policies should be non-negotiable, and which ones can be conceded in exchange for broader support.

FIND CONSERVATIVE SUPPORT FOR CARBON PRICING

Because Maryland has such a dominant Democratic majority, CCAN could focus only on support from Democrats to get the votes needed to pass a carbon pricing bill. A more far-sighted approach would be to build a coalition that eschews partisanship, because bipartisanship could lead to greater action on climate change in future. In the 2017 Maryland General Assembly, an energy efficiency bill that had enjoyed bipartisan support in the past lost some of its support by Republicans ("Maryland LCV 2017 Environmental Scorecard," 2017). By reaching out to conservatives, CCAN can help decrease the partisanship that has become prevalent in public debate about climate change. I suggest talking with RepublicEN, a conservative nonprofit promoting carbon taxation, and with Conservatives for Clean Energy, a nonprofit currently operating in North Carolina and Virginia.

One potential strategy for gaining support from Republican representatives is to focus on carbon pricing as a way to improve the health of the Chesapeake Bay. Several Republican representatives list the Chesapeake Bay on their websites as one of their priorities (see, for example, the websites of Senator Brian Simonaire, Delegate Meagan Simonaire, and Delegate Christian Miele). Delegate Susan Aumann is a Republican on the House Committee on Economic Matters who prioritizes the health of the Bay and preserving farmland ("Susan Aumann for delegate," n.d.). CCAN can develop a persuasive, compelling argument that mitigating climate change will protect the Chesapeake Bay and surrounding wetlands, and will preserve productive farmland.

EDUCATION

Members of the environmental advocacy community have different opinions about the best environmental solutions. When the environmental community is at its most effective, groups are working towards a common goal, coordinating with each other, and playing to their strengths. At its worst, environmental groups publically work against each other. Initiative 732 in Washington State was a ballot initiative in November of 2016 that would have implemented the first state-level carbon tax in the country. While some environmental groups supported the initiative, other environmental groups campaigned actively against it because the revenue would not have been used to invest in green energy research and development (Roberts, 2016).

I believe that some of the environmental groups opposing the Washington carbon tax fundamentally misunderstood how carbon pricing works. Because the carbon tax would have made fossil fuel use more expensive, it would have given private firms incentive to innovate their own solutions. Firms would not have needed additional funds to innovate (though they would have happily accepted them). As CCAN campaigns for a price on carbon in Maryland, an important piece would be to educate leaders within environmental advocacy groups about how carbon pricing works, and how revenue does not need to be spent on renewable energy solutions in order to succeed. That education can happen quietly in private meetings, to strengthen relationships and build mutual understanding before moving into the public arena.

Education is also needed among grassroots supporters. Because many people do not understand cap and trade, they do not know whether to support it. CCAN can sponsor a round of educational sessions for active grassroots members. In May of 2017, Governor McAuliffe of Virginia ordered Virginia's Department of Environmental Quality to devise carbon allowances for power plants that could be traded with carbon markets outside of Virginia. The Virginia carbon market regulation was not widely understood when first announced, but knowledgeable leaders within the environmental community explained the policy to the rest of the leadership. Then the Virginia Conservation Network sponsored a series of educational workshops for grassroots members to learn about cap and trade (author's personal experience, 2017). This effort helped create a cohesive environmental coalition that promoted widespread support by their membership, with no obvious public environmental campaigns against the regulation.

Probably the biggest reason why a carbon market in Virginia was less contentious than a carbon tax in Washington was that the Virginia regulation will not bring in new revenue for the government. Whenever new revenue becomes available for distribution, people are likely to loudly disagree on how to use it. The more flexibility CCAN has in its position on how to distribute carbon market revenue, the more successfully it can build support for expanding cap and trade.

IDEAL DISTRIBUTION OF CARBON PRICING REVENUE

The ideal distribution of carbon pricing revenue would have four major results:

- Revenue-neutral or revenue-positive for low-income residents
- Neutral or positive impact on Maryland GDP
- Fund carbon emissions reduction projects that a carbon price does not otherwise address
- Avoid incentives for people to keep using fossil fuels

To achieve these goals, I recommend that the revenue be allocated:

- **50% Dividend to households**, with lower income receiving a higher dividend
- **20%** Offset **lower corporate taxes**
- **30% Complementary projects** that further reduce carbon emissions
    - Grants to low-income households and businesses to **improve energy efficiency**
    - Infrastructure that reduces carbon emissions from **vehicles**

Figuring out the precise impact of revenue distribution designs is beyond the scope of this project. Breslow and Pickens (2018) of Climate XChange have conducted technical analysis of the economic impact of variations of the slow-rise carbon fee and dividend put forward in RCCCI. I highly recommend that CCAN study the analysis they will publish in the months ahead (Breslow, personal communication, March 16, 2018).

In the meantime, applying lessons learned from the literature is useful. Returning the entire revenue to residents as a flat dividend is easy to understand, transparent, seems fair, and helps low-income residents. The drawback of a 100% fee-and-dividend plan is that it would lower the state GDP (Carbone et al. 2013). Not only would this aspect cause opposition from the business and financial sectors, it would also hurt some low-income residents. When economic growth slows, jobs are lost and wages stagnate ("Chart book: the legacy of the Great Recession," 2018).

50% PROGRESSIVE DIVIDEND FOR HOUSEHOLDS

Without considering how revenue is spent, a carbon price is regressive because it impacts low-income households more than high-income households. Research indicates that low-income households can be fully compensated for the extra expense of a carbon fee without using 100% of the revenue for a dividend. Berry (2017) found that a flat dividend of just 58% of the tax revenue would be sufficient to offset the regressive nature of the carbon tax in France. Even better**, if the dividend is not flat but is instead adjusted to give a higher rebate to low-income households, the policy will become progressive with just 37% of revenue used as a dividend**. This result held true regardless of the size of the carbon fee. The specific results apply to France only, but imply that similar trends are possible in Maryland. Consequently, **I recommend that 50% of the revenue from expanded cap and trade be used as a dividend that is inversely proportional to income: the lower the household income, the higher the rebate.** I also recommend more economic modeling of the combined impact of tax cuts and progressive dividend on Maryland GDP and on low-income residents.

Breslow and Pickens (2018) found that 60% of revenue from a carbon fee in Maryland is needed to be rebated to households to protect 85% the households in the lowest quintile of income. Their model was based on rebating some of the remaining revenue to employers, with no tax cuts, and did not incorporate a change in GDP. More analysis needs to be conducted for Maryland on the combined impact of household rebates and tax cuts. Models need to include the impact of the change in state GDP on low-income residents.

20% OFFSET OF CORPORATE TAX

In a model of a national carbon tax, when 100% of revenue is used to offset corporate taxes, the GDP increased compared to a BAU economy (Carbone et al., 2013). Using a portion of Maryland's carbon revenue to offset corporate taxes would lower any negative impact on GDP from other aspects of the expanded cap and trade. It would also help CCAN gain support from the business and financial sectors.

The two carbon fee-and-dividend options distribute 25% of revenue as dividends to businesses, with priority given to "vulnerable entities" ("RCCCI: House Bill 939 Summary," 2018). I think this distribution design is inferior to an across-the-board corporate tax break because it depends on correctly predicting which businesses will be more vulnerable than others. It promotes the perception of favoritism for businesses that qualify and encourages lobbying for qualification by industry groups. As discussed in the section about impact on gasoline prices, businesses adversely affected by higher gas prices include restaurants and entertainment, two sectors that may not be thought of as vulnerable.

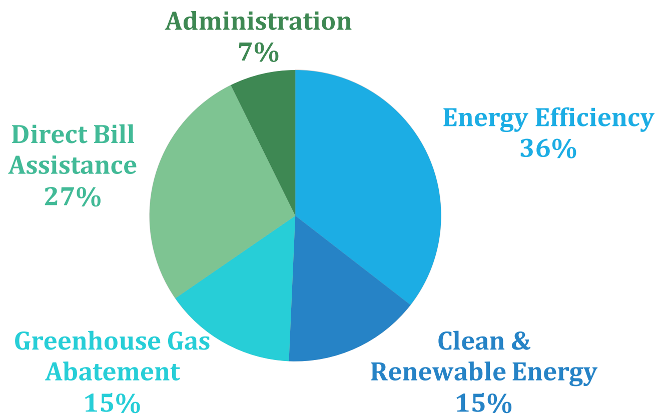
The only entities that will not benefit from a lower corporate tax are those that do not pay corporate tax: nonprofits and government entities. This category of organizations should receive a dividend proportional to their number of employees.

30% COMPLEMENTARY PROJECTS TO FURTHER REDUCE CARBON EMISSIONS

I recommend focusing this portion of the revenue only on lowering barriers to reducing emissions. One major barrier is upfront costs of energy efficiency improvements. Though energy efficiency upgrades have a high return on investment, low-income households and businesses do not have available funds to invest. Revenue can be used as grants to help residents, businesses, and landlords improve energy efficiency. This is much better use of funds than RGGI's current use of 27% of its revenue to assist with direct bill pay, as shown in Figure 8. Bill assistance does not eliminate the source of problem of high energy bills or high carbon emissions.

Part of this portion of revenue can be used to overcome the obstacles to consuming less gasoline. As discussed in the section on gasoline prices, a higher gasoline price alone is not sufficient to change diving behavior. In Maryland, powering electric vehicles uses carbon emissions equivalent to a conventional car getting 41 miles per gallon (mpg), with regions of the state achieving over 50 mpg (Reichmuth, 2018). Investing in electric vehicle charging stations and other infrastructure would help people transition off of gasoline-powered vehicles. This large expenditure makes sense for the government because the private market may choose not to invest in it. Maryland can also use this portion of revenue to expand and upgrade public transportation.

Figure 8: Distrubtion of $63.8 Million in RGGI Revenue By Maryland in 2015



Source: The Investment of RGGI Proceeds in 2015, by RGGI, Inc. (2017)

LIMITATIONS:

My recommendation is based on the assumption that carbon allowances would increase by 7% per year. More sophisticated economic modeling is required to more accurately predict the future price of carbon allowances in Maryland. Further economic analysis by Climate XChange and others is essential to determine the correct percent of revenue to be rebated to residents from an expanded cap and trade policy. Further economic analysis is also needed to determine the impact of a carbon price on Maryland's GDP of revenue used for rebates versus reduction in corporate, income, property, and sales taxes.

WHAT CAN BE CONCEDED?

The process of building a broad coalition necessarily requires allying with groups who disagree on some issues. Maryland currently has many carbon reduction policies, some of which are more effective than others, and some of which are redundant. The non-essential elements of carbon reduction policy can be useful in negotiation with potential allies. Knowledge of which policies are less essential and effective than others will help CCAN prioritize campaign efforts and resources.

RENEWABLE ENERGY PORTFOLIO STANDARDS

As discussed in the Literature Review, an RPS in combination with cap and trade is redundant, adds cost, and actually prolongs the use of coal (Böhringer & Rosendahl, 2010).

CLEAN CARS PROGRAM

Assuming that a national fuel efficiency standard is not abolished, the current structure of higher standard within the state of Maryland will not result in overall lower emissions, though emissions in Maryland will be lower (Schmalensee & Stavins, 2017). A price on carbon will incent people to purchase more fuel-efficient vehicles.

ALLOCATION OF REVENUE

Revenue can be used to win over allies, and there is a lot of room to slice up the revenue pie in different ways. I propose that adjusting the percentages will still result in a positive outcome for society. Using some of the revenue to offset lower income tax or sales tax will probably lower the Maryland GDP less than using the revenue for dividends, but lowering those taxes will have a less positive effect on GDP than lowering corporate taxes (Carbone et al., 2013). However, earmarking the revenue for specific projects or stakeholders could result in fewer overall benefits for vulnerable sectors and could be perceived as favoritism.

EXPANDING CAP AND TRADE INSTEAD OF A CARBON FEE

Though my analysis shows that expanding cap and trade is more effective at reducing carbon emissions at lower cost, a carbon fee-and-dividend is also clearly better for the climate than continuing with business as usual. If public opinion and political will cannot be swayed to expand cap and trade, a slow-growth carbon fee would be a good substitute. Any carbon policy should have a regular review process designed into it. Once a small price on carbon is in place, it can be raised if needed (or if it is a cap, it can be lowered at a faster rate). Public opinion may very well become more favorable once the policy is in place. In British Columbia, where a carbon tax was implemented in 2008, public opinion has been tracked annually. When the tax began at $8/mt$CO_2$ (in U.S. dollars), 60% of British Columbians polled were against the tax. In 2015, after the tax had ratcheted up to $24/mt$CO_2$, only 42% opposed it. (Murray & Rivers, 2015). Any way to put a price on carbon emissions will send a signal to the market that will result in at least some emissions reductions. Once established, the policy can be strengthened.

WHERE TO HOLD THE LINE

The essential components of a carbon price policy are:

- The price of carbon should **increase over time** until it equals the social cost of carbon.
- The policy should have a **periodic review mechanism** built into it with the ability to adjust the policy to be more effective.

- Exemptions from the carbon price should be extremely low in number and well-justified. **Carbon pricing promotes innovation. Exemptions do not.**
- Revenue should not be used in a way that prolongs the use of carbon-based fuels.
- Revenue should be used to offset the costs of the carbon price for low-income households.
- **Distribution of revenue should be transparent**, and claims of revenue neutrality should be supported by data annually.
- The policy should be designed to **avoid the need for a renewal date**. If people perceive that it will go away, they will not make long-term changes to lower their carbon emissions.

Even with all of the policies Maryland has already put in place to reduce carbon emissions, it will not achieve its goal of 40% reduction in carbon emissions by 2030. Adding one far-reaching policy that can surpass the goal is better than adding several piecemeal policies that are redundant and leave gaps. A price on carbon is the simplest, most efficient way to prompt carbon reductions across sectors. If CCAN campaigns for Maryland to leave RGGI to join the California, Ontario, and Québec cap and trade, it will push decision makers and environmental advocates to think bigger. While a carbon fee and dividend will lower emissions and return money to residents progressively, expanding cap and trade can do even more. Expanding cap and trade will lower carbon emissions by 47% at a lower cost of expenditure per ton of carbon pollution avoided. Revenue allocation should be laser focused on three goals: offsetting energy and fuel expenses for residents, especially for low-income households, keeping Maryland's economy healthy, and removing obstacles to reducing carbon emissions.

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APPENDIX A: MAIN ELEMENTS OF THE REGIONAL GREENHOUSE GAS INITIATIVE (RGGI)

Source: RGGI, Inc. (2018) unless otherwise specified

- History:
  - Agreement between 9 northeastern states, including Maryland, Delaware, New York, Connecticut, Rhode Island, Massachusetts, Vermont, New Hampshire, and Maine.
  - New Jersey may rejoin RGGI soon. Virginia is developing a plan to link with RGGI.
  - First allowance auction began in 2008, with cap placed in January, 2009.

- The Cap on Carbon covers all of the states participating in RGGI.
  - Covers only power plants that have at least a 25 Megawatt capacity.
  - Covers only electricity generated within the RGGI states.
  - Set to lower by 30% between 2020 and 2030. This is a steeper reduction than originally planned, and was decided during the 2016 Program Review.
  - 1 allowance permits a power plant to emit 1 short ton of carbon dioxide.
  - Regulatory period is 3 years, at which point power plants must retire allowances for the all of the carbon dioxide emitted.

- Allowance distribution is predominantly through an auction.
  - The auction is held quarterly.
  - Anyone can bid in the auction, in blocks of 1000 allowances.
  - The clearing price of the auction sets the price for allowances for all bidders.
  - Parties who bid higher get first dibs on allowances.
  - Allowances may be sold to anyone on the secondary market, in any size block.
  - Allowances may be banked to be retired in future years.

- Revenue
  - RGGI states agreed to spend at least 25% of their revenue on green energy and/or to benefit consumers (RGGI MOU, 2005). Some states have invested a much larger percent.

APPENDIX B: MAIN ELEMENTS OF HB 939:

THE REGIONAL CLIMATE COST CONTAINMENT INITIATIVE (RCCCI)

Source: RCCCI (2018)

- History in Maryland General Assembly:
    - 2018 Maryland house of delegates bill 939
    - Sponsors: Delegate Benjamin f. Kramer & Delegate David Fraser-hidalgo
    - Received an unfavorable report by the house committee on economic matters
    - Only Delegate Valderrama and Delegate Kramer voted against the unfavorable status.

- Main features of RCCCI:
    - A carbon fee will be levied on all fossil fuels and other sources of greenhouse gases (in my analysis, I have focused only on CO_2).
    - At the first point of sale in state for petroleum products.
    - Annually by electricity providers based on their fuel mix for both in-state and out-of-state generation.
    - The cost paid by electricity providers to RGGI will be deducted from the carbon fee, provided that it is less than the pollution charge.
    - Public transportation is exempt.

- The charge will begin at $15/mtCO2 in 2015, and increase by $5/mtCO2/year until leveling out at $45 in 2025.

- After 3 years, and every 2 years after that, the carbon fee will be evaluated and recommendations will be made to adjust it as needed to address
    - Inflation
    - progress toward achieving goals.
    - Mitigation of negative impacts on sectors.
    - To better account for total lifecycle emissions of fuels.

- Distribution of Revenue
  - 10% Green Infrastructure Fund
    - Invested in
      - Resiliency projects
      - Projects reducing emissions from transportation
      - Reduce emissions, especially through energy efficiency for low-income housing and renters
      - Help workers who lost jobs due to carbon cost transition to other jobs
    - 50% distributed to localities, prioritizing low-income communities, and 50% to state
  - 90% Greenhouse Gases Charges Fund
    - 75% for Household Rebate Account
      - 20% to households in lowest 2 quintiles of income
      - 10% of money from sales of heating fuels for households will be used for the Energy Assistance Program
      - Remaining funds will be rebated equally to all adult residents in the state, with residents under 18 receiving ½ the amount of the adult rebate.
    - 25% for Employer Rebate
      - Priority for business sectors that have high energy demand, and for non-profit and government entities
      - Remainder divided among employers based on number of employees

- This plan will go into effect only when 2 of the following enact a similarly stringent carbon price:
  - member states in RGGI and/or
  - a bordering state or Washington DC.

APPENDIX C: CALIFORNIA CAP AND TRADE AB 32

Source: Center for Climate and Energy Solutions (n. d.) except where otherwise noted.

- History
    - AB 32, called the California Global Warming Solutions Act, was passed in 2005. It authorized a suite of climate change initiative, including cap and trade.
    - In 2016, SB 32 was passed to extend the California Global Warming Solutions Act to 2030.
    - In 2017, the California Supreme Court upheld the legality of AB 32 (Whitcomb, 2017).
    - The cap began in 2013, covering only emissions from power plants, included imported electricity, and industrial sources
    - In 2015, the cap was expanded to also cover distributors of natural gas and petroleum.
    - Linking with other carbon markets:
        - Québec linked its carbon market to California in 2014.
        - Ontario linked its carbon market to California and Québec in 2018.
        - The carbon regulations in Ontario and Québec are similar to, but not identical to, California.

- Scope
    - The cap now covers 85% of the state's greenhouse gas emissions.
    - AB 32, which includes the cap and trade along with other greenhouse gas reduction policies, is projected to lower greenhouse gas emissions by 40% from 2020 to 2030.
    - The cap covers other greenhouse gases in addition to carbon dioxide:
        - methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride, and other fluorinated greenhouse gases
    - Other greenhouse gases are measure in equivalencies of metric tons of CO2.
        - The equivalencies are based on the heat-trapping ability of these gases. If gas that traps more heat per molecule than CO2, then proportionally less than 1 mt of that gas will be equivalent to 1 mt CO2 (mtCO2e).
    - Cap applies to sources emitting at least 25,000 mtCO2e per year.
    - 1 allowance permits a regulated entity to emit 1 mt CO2e.

- Allowance Market
  - Initially, most allowances were distributed for free to covered utilities, with the understanding that the revenue from sales of allowances would be used to offset the cost of electricity for consumers.
  - California is transitioning to distribution of allowances through an auction, similar to RGGI.
  - The California, Ontario, and Québec conduct joint auctions of allowances, and allowances can be traded across all three jurisdictions.
  - Allowances can be banked for future use.

- Revenue
  - Must be spent on environmental improvement, with priority on air quality
  - At least 25% of funds must be for programs benefitting disadvantaged communities

APPEDNDIX D: METHODOLOGY FOR PROJECTING CARBON EMISSIONS REDUCTION

SLOW-RISE CARBON FEE AND DIVIDEND:

I based this option on the RCCCI. I used the emissions projection provided by Marc Breslow (March 5, 2018) in his testimony before the Maryland House of Delegates Committee on Economic Matters. Breslow (2018) used the Carbon Tax Assessment Model (CTAM) with data on Maryland. He projected carbon emissions in 2030 under Business as Usual and a Slow-rise carbon fee and dividend option. I assumed that the carbon emissions would decrease at a steady linear rate between 2020 and 2030.

FAST-RISE CARBON FEE AND DIVIDEND:

Because I did not have access to the CTAM model for Maryland, I could not make direct predictions using the model. Instead, I used the publically available CTAM model for Washington State (Mori, Hammerschlag & Co., 2015). I assumed that the percent change in carbon emissions in Washington would be the same as the percent change in Maryland if taxes increased at $5/year instead of $10/year. I applied the percent change in Washington emissions, which I could project using the model, to calculate the emissions in Maryland under a fast-rise fee-and-dividend. This calculation was for the year 2030. I then assumed a steady linear rate of emissions reductions between 2020 and 2030.

Table 10: Estimating emissions for fast-growth carbon fee and dividend in Maryland in 2030.

Millions of metric tons of CO_2 ($MmtCO_2$)

	Washington	Maryland
$45 in 2030 (slow- growth fee and dividend)	68.64	71.41
$115 in 2030 (fast-growth fee and dividend)	60.42	62.86

This option involves leaving RGGI and linking with California. Under this option, Maryland's carbon cap would reduce at the same rate as California's, and would cover the same sectors of carbon emissions. Based on the pattern of carbon missions in Maryland, I estimated that applying California's cap to Maryland would cover 90% of Maryland's carbon emissions. I assumed that the 10% of Maryland's emissions not covered by the cap would increase at a rate of 1% per year. I calculated the annual percent decrease in California's cap and applied that to 90% of the projected emissions in 2019, the year before the new cap would go into effect.

Table 11: Calculations for Total Emissions in Maryland Per Year Under an Expanded Cap Linked with California

Year	California Cap Millions of metric tons of CO_2 ($MmtCO_2$)	Percent decrease in cap from previous year	$MmtCO_2$ covered under cap (90% of total Maryland emissions)	$MmtCO_2$ not covered by cap (assume 10% in 2020, increasing at 1%/year)	Total $MmtCO_2$ in Maryland
2019	346.3	N/A	N/A	N/A	90.7
2020	334.2	3.5%	79.0	8.8	87.8
2021	320.8	4.0%	75.9	8.9	84.7
2022	307.5	4.1%	72.7	9.0	81.7
2023	294.1	4.4%	69.6	9.0	78.6
2024	280.7	4.6%	66.4	9.1	75.5
2025	267.4	4.7%	63.2	9.2	72.5
2026	254.0	5.0%	60.1	9.3	69.4
2027	240.6	5.3%	56.9	9.4	66.3
2028	227.3	5.5%	53.8	9.5	63.3
2029	213.9	5.9%	50.6	9.6	60.2
2030	200.5	6.3%	47.4	9.7	57.1

Sources:

- Carbon emissions in 2019: Maryland Open Data Portal
- California emissions in 2019-2030: Regulation for the California Cap on Greenhouse Gas Emissions and Market-Based Compliance Mechanisms
  Subarticle 6: California Greenhouse Gas Allowance Budgets
  - § 95840. Compliance Periods
  - § 95841. Annual Allowance Budgets for Calendar Years 2013-2050.

APPENDIX E: METHODOLOGY FOR CALCULATING COST OF EXPENDITURES PER TON OF CO2 AVOIDED

PREDICTING FUTURE PRICE OF CARBON ALLOWANCES

If Maryland links with California and other carbon markets, and they collectively sell their allowances through one auction, Maryland will have the same price per ton CO_2 as California. One might expect that the trend in California's prices from 2015 to 2017 would continue in Maryland in the future. That would be unlikely to be exactly the case, because the jurisdictions linking up do not have completely identical complementary carbon policies.

Because the cap is lowered yearly, making allowances scarcer, and because allowances can be banked for use in future years as the cap decreases, allowances essentially become a nonrenewable resource. Once an allowance is used up, it is gone. In environmental economics, the Hotelling Theory predicts that the price of nonrenewable resources will increase at the rate of interest. Therefore, to predict the future price of allowances, I used an annual interest rate of 7%. I used the starting price of for 2018 of $15.45, which was the price of allowances on the secondary market on the first auction day of 2018 (California Carbon Dashboard, 2018).

TOTAL COST OF EXPENDITURES

For each year, I multiplied the price per ton of carbon by the total tons of carbon emitted. I then calculated the net present value of the total costs for all the years from 2020 to 2030.

Table 12: Total Cost of Expenditures in Millions of Dollars

Year	Net Present Value Discounted 7%	Net Present Value Discounted 3%	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Slow-Growth Fee & Dividend	$18,549	$24,494	$1,334	$1,743	$2,136	$2,510	$2,867	$3,207	$3,529	$3,450	$3,371	$3,292	$3,213
Fast-Growth Fee & Dividend	$30,133	$40,675	$1,334	$2,160	$2,935	$3,660	$4,335	$4,958	$5,531	$6,054	$6,526	$6,947	$7,318
Expand Cap and Trade	$11,152	$14,333	$1,525	$1,548	$1,568	$1,586	$1,601	$1,613	$1,622	$1,629	$1,632	$1,633	$1,630

TOTAL TONS OF CO2 AVOIDED

To find the tons of CO2 avoided, for each year I subtracted the tons of emissions from each option from the tons of emissions from BAU. I then calculated the net present value of the total tons of CO2 avoided.

Table 13: Millions of Total Tons of Carbon Dioxide Avoided Compared to Business As Usual

Year	Net Present Value Discounted 7%	Net Present Value Discounted 3%	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Slow-Growth Fee & Dividend	38.62	53.27	0.67	1.78	2.90	4.02	5.14	6.26	7.38	8.50	9.62	10.74	11.86
Fast-Growth Fee & Dividend	62.21	86.13	0.67	2.56	4.46	6.35	8.25	10.15	12.04	13.94	15.84	17.73	19.63
Expand Cap and Trade	86.37	118.93	1.77	4.21	6.64	9.09	11.53	13.95	16.40	18.84	21.26	23.70	26.14

COST OF EXPENDITURE PER TON OF CO2 AVOIDED

I then divided the total cost of expenditures from Table 12 by the total tons of carbon avoided in Table 13.

Table 14: Cost of Expenditures Per Ton of CO2 Avoided from 2020 to 2030 (Net Present Value)

	7% Discount Rate	3% Discount Rate
Slow Growth Carbon Fee & Dividend	$480	$460
Fast Growth Carbon Fee & Dividend	$484	$472
Expanded Cap	$143	$104

The allowance price would have to increase by **26% per year** for the cost of expenditure per ton CO2 avoided to match that of the slow-growth carbon fee. It would have to grow over **4 times faster than my model assumes.**

The allowance price would have to increase by **10%** per year in order to exceed the price per ton of carbon under slow-growth carbon fee plan in 2030.

As a comparison, the allowance price in California has increased by approximately 5% per year over the past three years.

APPENDIX F: ADDED COST OF CARBON PRICE ON ONE GALLON OF GASOLINE

Every gallon of gasoline burned releases 8.89 kilograms (kg) of carbon dioxide.
(Hafstead & Picciano, 2017).

Carbon prices are based on 1 metric ton (mt) of CO_2.

With 1000 kg in 1 metric ton, gasoline combustion releases 0.00889 metric tons of CO_2.

$$Price\ of\ carbon\ per\ gallon\ of\ gasoline = Price\ per\ mt\ of\ CO2 * 0.00889$$

APPENDIX G: METHODOLOGY FOR CALCULATING MILES PEOPLE ARE WILLING TO DRIVE AVOID A CARBON PRICE ON GASOLINE

Table 16: Assumptions used in calculations of distance people are willing to drive to avoid a carbon price on gasoline

Assumptions		Sources
Average miles per gallon for cars and light trucks	24.7	Reuters Article: U.S. vehicle fuel economy rises to record 24.7 mpg: EPA (2018)
Gallon per tank	23.9	See Table 16 below
Value of time ($/hour)	25	Median hourly wage often assumed in cost effectiveness analysis
Price per gallon ($) (no Carbon fee)	2.45	Estimate based on Gasbuddy.com on April 6, 2018
Kilograms of carbon per gallon of gasoline	8.89	Resources for the Future Blog: Calculating Various Fuel Prices Under a Carbon Tax (2017)
Cost per mile driven ($/mile) in 2018	0.545	IRS Standard Mileage Rate (2018)
Increase per year in cost per mile driven ($/mile)	0.00681	Regression of IRS Standard Mileage Rate from 1997 to 2017, adjusted to constant 2018 dollars. ($p<0.001$)
Driving speed (miles per hour)	60	
No change in gasoline price over time, other than in carbon price		A regression of historic gasoline prices over from 1929 to 2015 based on constant 2015 dollars yielded a p-value of 0.20. Source of data: Energy.gov Office of Energy Efficiency and Renewable Energy (2016)
No difference in gas prices between states other than the carbon price		
Tank completed filled at gas station		
Driver does not combine trip to gas station with any other purpose (e.g. going to work or shopping)		

AVERAGE GALLONS PER TANK

I created a weighted average of gas tank sizes for sport utility vehicles (SUVs), light duty trucks, and cars, based on the number of each vehicle in each category sold in the United States in 2017 (Source: Wall Street Journal: Market Data Center: Auto Sales, n. d.).

Table 16: Average Gallons per Tank of Personal Vehicles

Type of Vehicle	Gallons Per Tank	Number sold in US in 2017	Proportion of total vehicles sold	Weighted average	Source of Assumption for Gallons Per Tank
Car	14	1,374,507	0.328	4.59	Quicken Loan Blog: How much does it cost you to fill up? (2013)
SUVs and Vans	25	746,837	0.178	4.45	Cars.com: 2017 Full-Size SUV Capacities
Light Duty Truck	30	2,069,845	0.494	14.82	Cars.com: 2017 Full-Size SUV Capacities
Total		4,191,189	1.000	23.86	← Average Tank Size

DISTANCE WILLING TO DRIVE TO AVOID A CARBON PRICE ON GASOLINE

Based on the assumptions in Table 15, I used the following formula to calculate distance drivers are willing to drive to go to an out-of-state gas station:

$$Distance\ willing\ to\ drive = \frac{\dfrac{\left(\dfrac{P*K}{\dfrac{1000kg}{mt}}\right)*T}{C+\left(\dfrac{V}{S}\right)}}{2}$$

Where:

P = Carbon Price per metric ton
K = kilograms of CO2 released per gallon
1000 kg/mt = conversion factor to change kilograms to metric tons
T = Gallons per tank
C = cost per mile driven
V = value of time
S = driving speed
2 = denominator used to calculate the 1-way distance to gas station for a round-trip trip

SENSITIVITY:

If any one of my assumptions is inaccurate, it changes the distance people are willing to drive.

THE VARIABLES THAT WOULD BE LIKELY TO *DECREASE* THE DISTANCE PEOPLE ARE WILLING TO DRIVE:

Driving speed: If people drive even part of the distance at less than 60 mph.

Completely filling the tank: If people purchase less than a full tank of gas.

Average Tank size: Half of new vehicles sold in the US were light duty trucks. If the proportion of light duty trucks in Maryland is less than half of personal vehicles, the average tank size will decrease, making distance willing to drive decrease.

No difference in gas prices between states, other than the carbon price: As of the writing of this report, gas prices in DC and all states bordering Maryland are more expensive than gas prices in Maryland. If this trend continues, it will lower the distance people are willing to drive to buy out-of-state gas. Only West Virginia has gas prices equal to Maryland gas prices. Because the area of Maryland close to West Virginia has low population density, future lower gas prices in West Virginia would influence a relatively small number of Maryland drivers.

THE VARIABLES THAT WOULD BE LIKELY TO *INCREASE* THE DISTANCE PEOPLE ARE WILLING TO DRIVE:

Value of time: If people value their time at less than $25/hour

Wear and tear on vehicle: If people do not consider the full cost of driving extra miles.

Single-purpose trip: People usually combine gasoline purchases with other trips. If people are crossing state lines to for work or other purposes, that would increase the amount of gasoline purchased out-of-state.