Carbon pricing in Maryland: an initial analysis

An initial report on the potential impact of select scenarios for carbon pricing in the State of Maryland on emissions, revenue generation and industry output

February, 2022

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EXECUTIVE SUMMARY

This report is an initial analysis of how an economy-wide carbon price could impact Maryland. It considers various design elements to construct a carbon pricing policy—from how broadly to apply the carbon price to how to allocate the revenue raised by the carbon price. It also offers some initial quantitative analysis based on a range of scenarios.

Carbon pricing could play an expanded role as part of Maryland's broader policy mix to meet the goals spelled out in the Greenhouse Gas Reduction Act. Maryland already participates in a carbon pricing program through its participation in the multi-state Regional Greenhouse Gas Initiative, targeting the electricity-generation sector. However, a carbon price covering broader sectors in Maryland could play a secondary role, impacting statewide emissions. Furthermore, designing a carbon price while considering local circumstances should allow for a more Maryland-specific match, as the approach could be tailored across multiple different design characteristics.

This analysis modeled the application of a broad-based carbon price covering the energy and industrial sectors. It used three different prices ($40, $60, and $80 per metric ton carbon dioxide equivalents) and one sensitivity—adjusting the degree of consumer response to the carbon price - in transportation.

Initial conclusions of this analysis include the following:

- The planned coal power plant retirements that are not incorporated in the GGRA reference case could have a significant role in reducing carbon emissions in Maryland but would likely remain insufficient to meet the 40 percent reduction target compared to the 2006 emissions baseline.
- A scenario with a carbon price starting at $40 per metric ton carbon dioxide equivalents in 2023 and increasing by 5 percent per year could lead to emissions 4 percent lower than the reference case in 2030, which could be sufficient to meet the 40 percent reduction target.
- A carbon price at these levels may not enable Maryland to meet the 50 percent emission reduction as laid out in the 2030 GGRA Plan without additional policies to support decarbonization.
- A carbon price that starts at $80 per metric ton carbon dioxide equivalents with complementary transportation policies and long-term consumer behavior shifts could enable the reduction of 50 percent emissions relative to the 2006 baseline by 2030.
- Using revenue generated by a carbon price will likely be important to address the potential impacts of the carbon tax. Only a small share of revenues would be required to compensate households for higher fuel costs. Similarly, an investment in renewable energy deployment could support employment in these industries. These measures would likely still leave $2 billion in additional revenue available to fund other programs and initiatives, such as direct cash payments to Maryland households. Doing so could generate over 6,000 jobs through enhanced consumer spending by households, through a projected multiplier impact.

This analysis represents a first step to understanding the potential role of carbon pricing in Maryland. Following stakeholder consultations, a more detailed analytical exercise that takes advantage of a full suite of economic models should be used to provide deeper insights into the complex interactions that a carbon price creates within an economy.[1]

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[1] McKinsey & Company, Inc., Washington D.C. ("McKinsey") provided a fact-based analysis of the cost, macro-economic and carbon-emissions impact of potential carbon-pricing approaches, identified by MEA/State of MD, to help reduce carbon emissions statewide. The Deliverable(s) does(do) not constitute, and should not be interpreted as, policy, accounting, legal, tax or other regulated advice, or a recommendation on any specific course of action. The State of Maryland is solely responsible for all of its decisions, use of these materials, and compliance with applicable laws, rules and regulations

SECTION 1: INTRODUCTION AND CONTEXT

PURPOSE OF THIS REPORT

The focus on the impacts of climate change—nationally and at the state level—has prompted Maryland to evaluate its overall policies targeting greenhouse gas (GHG) emissions. Meeting Maryland's GHG reduction targets may benefit from a review of Maryland's energy policies. The Maryland Energy Administration (MEA) is tasked with advising the Governor of Maryland and the General Assembly on all energy matters.

The establishment of a carbon price within the State of Maryland is one of many potential ways to augment existing policies in place.

This report provides a high-level overview of the impact a carbon price could have on emissions, industry output, and revenue generation in the State of Maryland. It is the starting point of a conversation regarding the potential role carbon pricing could play and strives to create a transparent platform for that conversation. Further analysis should build on this initial evidence base to provide the information needed for implementing an appropriately designed carbon price.

Why carbon pricing and why now

The federal government has placed an increased emphasis on climate change and have stated goals of 50 to 52 percent reduction in U.S. GHG emissions by 2030, and 100 percent carbon-pollution-free electricity by 2035, and has rejoined the Paris Agreement, with its goal of limiting global warming well below 2 degrees Celsius.[2]

To achieve these targets may require industries to potentially alter their operations and explore adoption of new technologies across the economy. A well-designed carbon pricing program could help accelerate those changes by associating a cost to emissions international organizations have estimated that climate-related infrastructure investment should be about $6.9 trillion per year up to 2030, but in 2011 it was only $364 billion (World Bank; OECD; UN Environment, 2018). Carbon pricing could also promote cost-effective mitigation by giving businesses the flexibility to decide how to reduce their GHG emissions and generate revenue that could be used to address distributional impacts, reduce taxes, or make further investments in public goods. Addressing the impacts to a carbon price is an essential component of any program. These and some other examples are outlined in Exhibit 1.

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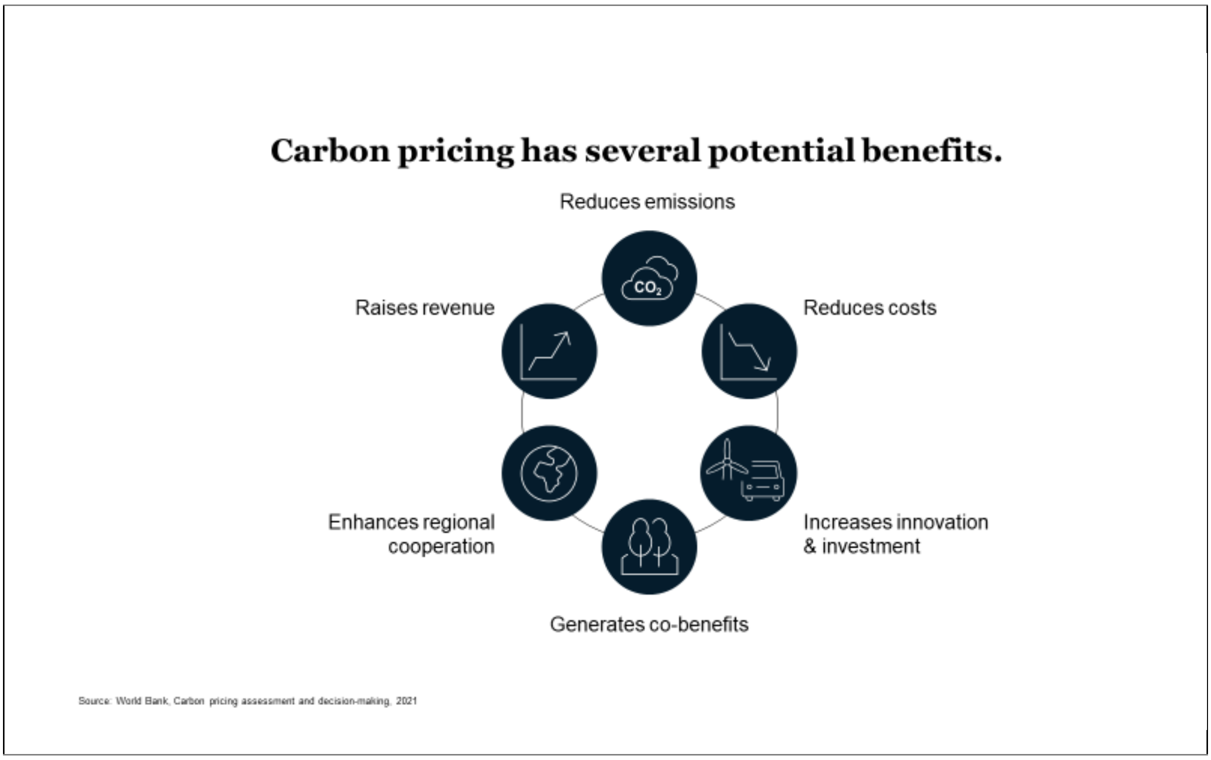
[2] White House fact sheet, April 2021.

Exhibit 1



Carbon pricing has several potential benefits.

Reduces emissions

Reduces costs

Increases innovation & investment

Generates co-benefits

Enhances regional cooperation

Raises revenue

Source: World Bank, Carbon pricing assessment and decision-making, 2021

Increasingly, states are looking at carbon pricing as an option that contributes to achieving their goals. Maryland is already a member of the Regional Greenhouse Gas Initiative (RGGI), which applies a carbon price in the electricity sector spanning nearly a dozen northeastern and mid-Atlantic states.[3] Other states are increasingly assessing carbon pricing: California and Massachusetts have already implemented state-specific policies, and Washington State is due to implement one in 2023.[4]

Goals and approach of this report

The Maryland Energy Administration (MEA) commissioned this research to contribute to the conversation about carbon pricing and the reduction of emissions more broadly in the State of Maryland.

Goals of this report

This report aims to determine the potential impact of a carbon price on emissions, industry output, and potential revenue generation in Maryland.

Specifically, this report has the following three goals:

1. **Create a common understanding:** Carbon pricing is a complex mechanism with multiple design considerations. This report strives to explain those design choices and educate stakeholders on the rationale for selecting one over the other.

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[3] As of January 2021, RGGI member states were Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, Vermont, and Virginia.

[4] Center for Climate and Energy Solutions.

2. **Provide initial quantification:** Evaluate - at a high level - the potential impact of a carbon price on industry output, revenue generation, and emission reduction. For each scenario developed, the report quantifies the potential impact, and which design choices could drive the largest impact.
3. **Discuss next steps—considerations for further evaluation:** The exploration of a carbon price is at an early stage; there are next steps to further understand the potential impact a carbon price could have on Maryland specifically.

This report was compiled by following a four-step process to build the potential scenarios, analyze the implications for Maryland, and consider the next steps.

The four-step process is detailed below:

1. **Clarify the Maryland context**
    - Review sector emissions and align on sectors to include
    - Discuss GGRA reports and how to incorporate the latest analysis
    - Outline sector mix and its impact on potential carbon pricing design

2. **Choose carbon pricing options**
    - Discuss different carbon pricing instruments (CPIs)
    - Evaluate different design considerations and suitability for context
    - Design scenarios to be analyzed

3. **Analyze carbon pricing impacts**
    - Review modeling output from analysis against emissions, industry output, and revenue generation
    - Discuss potential implications of results for Maryland
    - Align on model iterations

4. **Discuss conclusions and next steps**
    - Discuss final model output
    - Outline next steps to build on report and create more refined analysis

MARYLAND CONTEXT

A carbon price is not a one-size-fits-all instrument and typically benefits from being designed with the local context in mind to help achieve its goals, including mitigation of negative distributional impacts. Maryland's economic structure, emission profile, and existing climate targets and policies all influence the carbon price design and implementation strategy. Specifically, this section helps answer the following questions:

- What are the climate goals and targets currently in place in Maryland?
- What are the key climate and energy policies that are already enacted in Maryland?
- How is the Maryland economy structured, and how does that relate to its GHG emissions profile?

Emission targets and existing policies

A carbon price is an additional tool that could support the State of Maryland in meeting previously stated targets. It interacts with other climate and energy policies. Some policies, such as renewable energy targets, could be complementary or enhance action beyond the scope of a carbon price. Other policies, such as subsidies for fossil-fuel consumption, may counteract the price signal that a carbon price sends to households and businesses. Therefore, careful consideration is needed to understand how a carbon price could affect those policies.

Existing greenhouse gas emission targets

Maryland is currently pursuing ambitious targets that were laid out in the GGRA of 2016. This legislation calls for a 40 percent reduction in GHG emissions by 2030, compared to a 2006 baseline. This target is equivalent to gross emissions of 64.8 million metric tons (MMT) of carbon dioxide equivalent (CO_2e). However, it does not include negative emissions from carbon dioxide (CO2) sequestration by land and, as a result, is higher than the net emissions target specified by the GGRA.[5] The GGRA of 2016 was initially underpinned by the 2019 GGRA Draft Plan, which included a blueprint to achieve Maryland's emission-abatement targets.

In February 2021, the Maryland Department of the Environment (MDE) proposed the 2030 GGRA plan, which outlines additional policies for Maryland to consider. This proposed plan increases the proposed targets to a 50 percent reduction—or gross emissions of 54.1 MMT CO_2e—by 2030 and a net-zero state economy by 2045.[6] It is clear from the forecasts in the proposed plan that, if no additional climate policies are incorporated, the emissions will likely follow the 2020 Reference scenario (Exhibit 2). If all measures agreed in the 2019 GGRA Draft Plan are implemented, then the state's emissions will likely decline in line with the scenario from the GGRA Draft Plan of 2019 (dark blue line).

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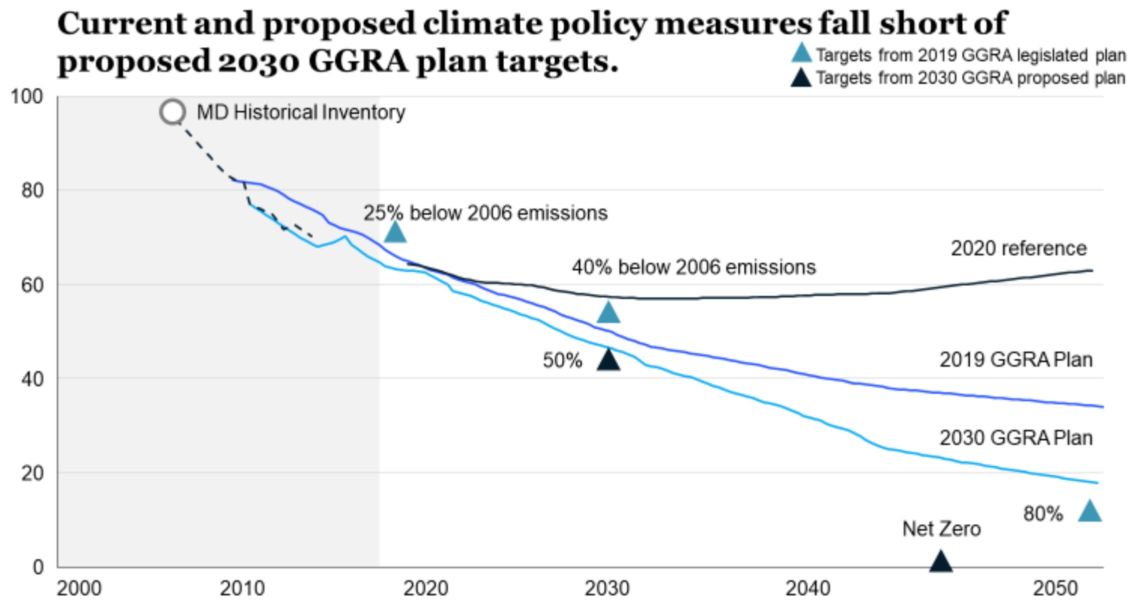
[5] The GGRA target is 53.0 million metric tons of MMT CO_2e. The increase in targets reflects an additional 11.8 MMT CO_2e from land sequestration.

[6] Once again, the net target proposed in the 2030 GGRA Plan includes CO_2 sequestration from land at 42.3 MMT CO_2e. It is 11.8 MMT CO_2e lower than the gross target.

Exhibit 2



Source: Department of Environment Greenhouse Gas Emissions Reduction Act

For the purposes of this analysis, the “baseline” scenario applies to the current statute, reflecting the continuation of current policies, but no additional policies, with the exception of an adjustment for known retirements of coal plants that were not previously included in the GGRA baseline (explained later). This allows for a comparison of the impact of a carbon price against business as usual.

Existing policies

The electricity-generation sector has two major policies that shape the emissions pathway for the sector: RGGI and the Renewable Portfolio Standard (RPS).

As previously indicated, RGGI is a regional agreement that explicitly sets a cap on emissions with the aim of reducing them by 30 percent between 2020 and 2030. Participating states established a cap-and-trade system across the electricity sector and market participants are required to comply with the regional cap-and-hold/cap-and-invest allowances equal to their CO_2 emissions.[7] As shown in Exhibit 3, RGGI came into effect in 2009, and the cap has decreased over time (excluding adjustments to accommodate new participating states).[8]

The explicit emission reductions enable them to be factored into the trend of emissions within the sector through 2030 in the absence of an additional carbon

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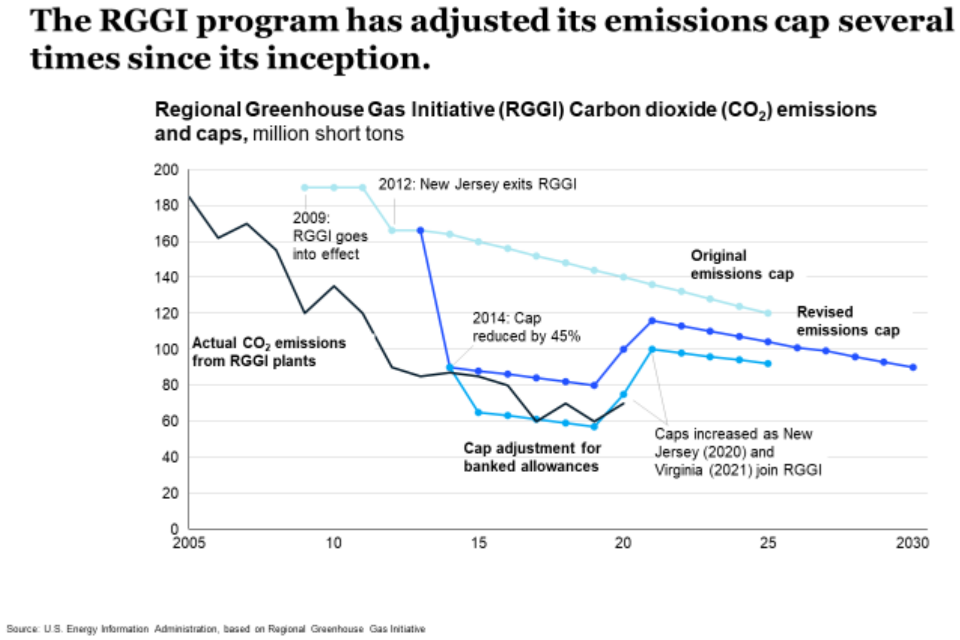
[7] The terms “cap-and-trade” and emissions trading system (ETS) are used interchangeably to describe a system where a quantity limit on emissions is placed and participating firms trade allowances to meet the overall emissions cap. This report will use the term “cap-and-trade” to avoid confusion.

[8] The RGGI cap is measured in short tons of CO_2 instead of metric tons of CO_2e. The difference arises because CO_2 is the only greenhouse gas regulated by the RGGI. One short ton is equal to 0.91 metric tons.

price in Maryland. Within the analysis, the carbon price “tops up” the RGGI price so that the total cost paid by firms equals the carbon level. For example, if the RGGI price is $8/ton and the tax level is $60, power generators will only pay $52/ton in tax. The overall cost to firms would be $52/ton + $8/ton = $60/ton instead of $68/ton.

Exhibit 3



The RGGI program has adjusted its emissions cap several times since its inception.

Regional Greenhouse Gas Initiative (RGGI) Carbon dioxide (CO_2) emissions and caps, million short tons

Source: U.S. Energy Information Administration, based on Regional Greenhouse Gas Initiative

Additionally, Maryland has an RPS that requires 50 percent of electricity sales from eligible renewable energy sources by 2030. This transition to clean energy through the RPS mandates emission reductions that could otherwise have been incentivized through a carbon price. The carbon price may likely need to be sufficiently stringent to incentivize emission reductions *beyond* what is mandated in the RPS.

The RPS can be achieved through renewable energy production or through the purchasing of renewable energy credits (RECs). The portion of the RPS that is met through the purchase of RECs does not reduce the inventory emissions in Maryland. This is defined in the GHG emissions inventory methodology to avoid the double counting of that renewable energy generation.[9]

All identified sectors included within this report have existing policies. However, despite the role that these policies will likely play in helping Maryland reduce those

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[9] State of Maryland 2017 Greenhouse Gas Emission Inventory Documentation: mde.maryland.gov/programs/Air/ClimateChange/Documents/MD%202017%20Periodic%20GHG%20Emissions%20Inventory%20Documentation.pdf

sectors' GHG emissions, they have not all been incorporated into the quantitative analysis because their interacting and overlapping effects could not be included.

Adjustment to the GGRA baseline based on coal retirements

Since the GGRA modeling was conducted, significant announcements concerning the retirements of high emitting coal plants have been released, which are detailed in Table 1 below.

Table 1: Announcements of coal plant retirements

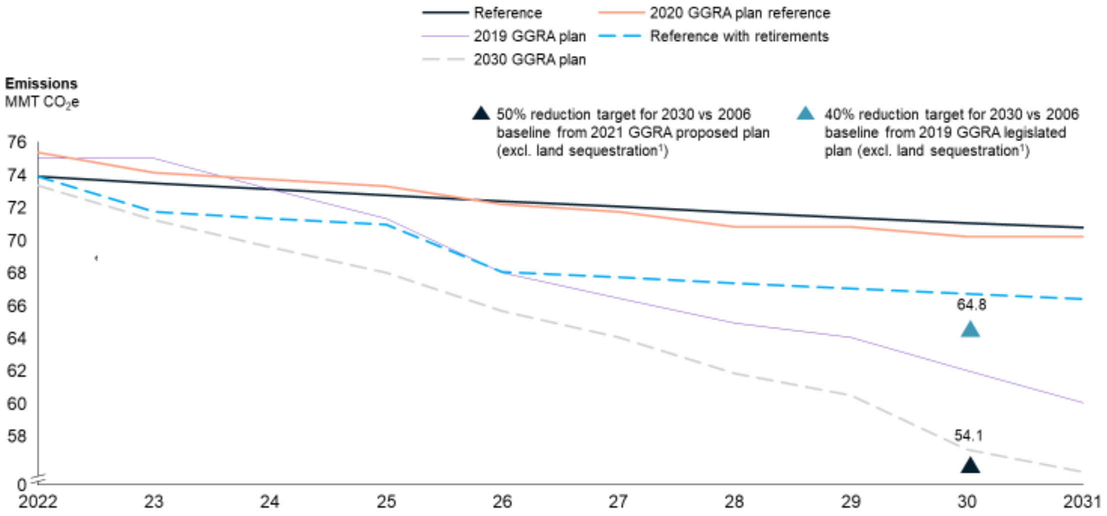
Coal Plant	**Nameplate capacity (MW)**	**2017 Emissions (tons CO_2)**
Brandon Shores	1,370.2	4.5 million
Herbert A. Wagner	1,058.5	Under 10,000
Morgantown Generating Plant	1,548	2.6 million

The baseline, or reference case for the GGRA assumes a reduction in coal generating capacity of 670 MW over the course of the 10 years to 2030, based on Integrated Planning Model (IPM) estimates. The amounts illustrated in the table are significantly more than that and therefore an adjustment to the GGRA baseline was conducted.

To complete this adjustment, simplifying assumptions were made that assumes the plant is operating at the same level with the same emissions as in the 2017 inventory, there is no ramp down and that the generation is replaced by the PJM mix. Therefore, the reduction is the difference between the coal generation and the emission by the PJM mix. This has the result of adjusting the baseline lower in terms of emissions by ~5 MMT CO_2e as illustrated in exhibit 4 below.

Exhibit 4:

Adjustment to reference case with coal retirements



1.Land sequestration was excluded as only gross emissions are considered. The increase in targets reflects an additional 11.8Mt CO_2 from sequestered land. Projected emissions taken from the 2030 GGRA reference scenario

Source: Enerdata; Maryland DoE GGRA plan 2030

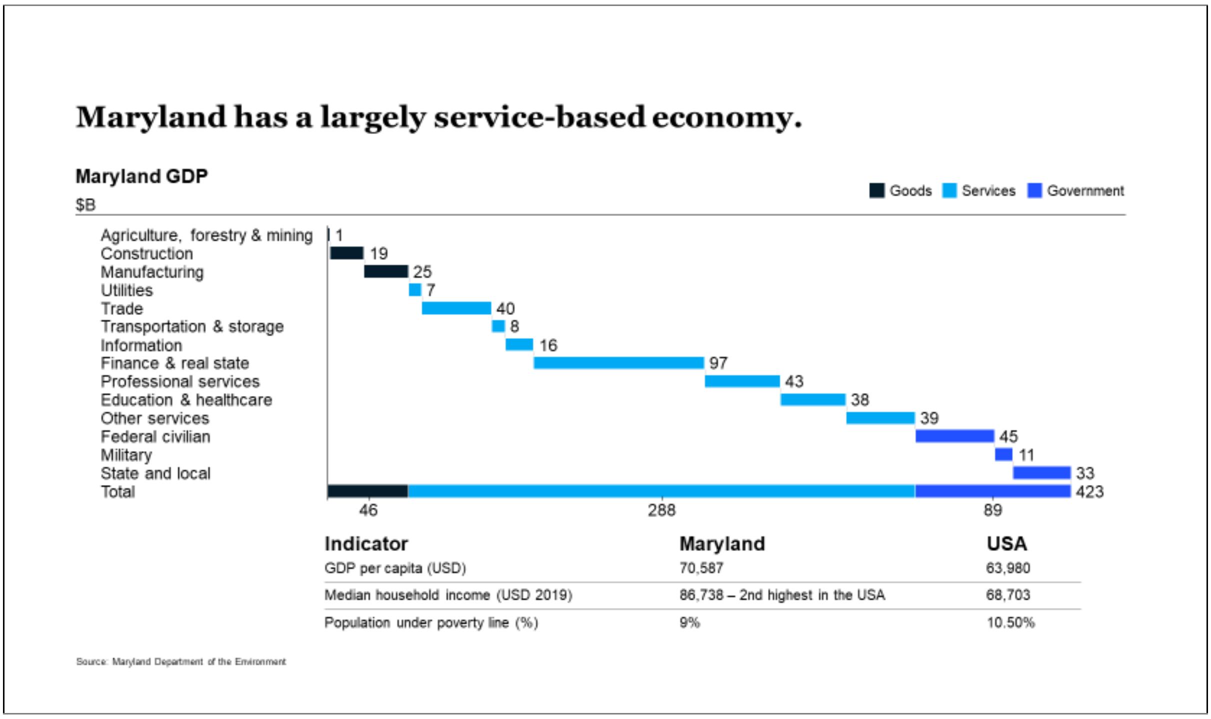
This adjustment forms the baseline for future comparison. Any subsequent comments in this report related to the 'baseline' are referring to the GGRA reference with the coal retirements removed.

Maryland's economy and emissions profile

The starting point of this analysis to assess a potential carbon pricing policy to help reach the GGRA target is to understand how Maryland's economy is structured and where GHG emissions are generated. This section addresses the linkages between Maryland's economy and its emission profile.

Maryland is a largely service-based economy, with only 11 percent of its gross domestic product (GDP) deriving from industry and services accounting for more than two-thirds of the economy (Exhibit 5).

Exhibit 5



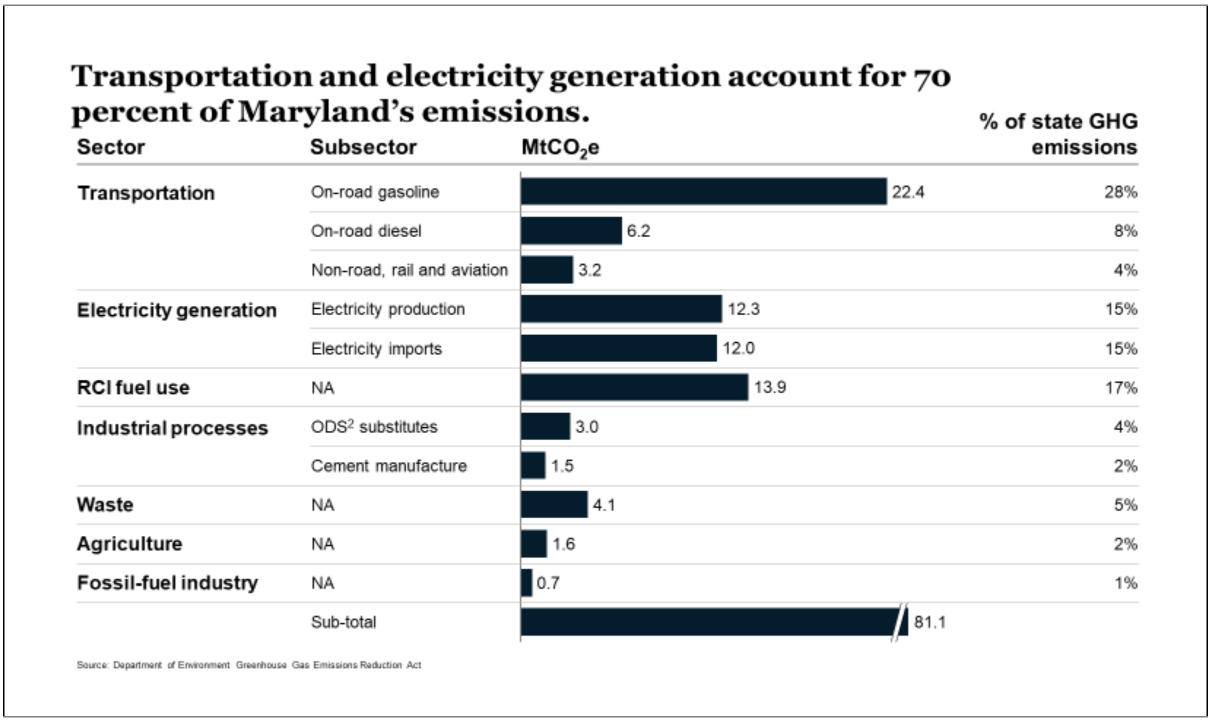
Maryland has a largely service-based economy.

Indicator	Maryland	USA
GDP per capita (USD)	70,587	63,980
Median household income (USD 2019)	86,738 – 2nd highest in the USA	68,703
Population under poverty line (%)	9%	10.50%

Source: Maryland Department of the Environment

This economic structure will likely have a material impact on how Maryland could appropriately apply any carbon price. As Maryland is a predominantly service-based economy, augmented by manufacturing, its emissions are driven by disparate energy consumers and a relatively small industrial base. This is reflected in the state's GHG emissions profile: 70 percent of emissions are accounted for by transportation and electricity generation, with the largest single contributor being on-road gasoline (Exhibit 6).

Exhibit 6



Transportation and electricity generation account for 70 percent of Maryland's emissions.

Sector	Subsector	$MtCO_2e$	% of state GHG emissions
Transportation	On-road gasoline	22.4	28%
	On-road diesel	6.2	8%
	Non-road, rail and aviation	3.2	4%
Electricity generation	Electricity production	12.3	15%
	Electricity imports	12.0	15%
RCI fuel use	NA	13.9	17%
Industrial processes	ODS[2] substitutes	3.0	4%
	Cement manufacture	1.5	2%
Waste	NA	4.1	5%
Agriculture	NA	1.6	2%
Fossil-fuel industry	NA	0.7	1%
	Sub-total	81.1	

Source: Department of Environment Greenhouse Gas Emissions Reduction Act

As traditionally associated with service-based economies, most emissions are produced by end users rather than by heavy industry. This could have an impact on choices regarding the point in the supply chain at which to apply a carbon price. For example, within the transportation sector, carbon pricing usually applies to the sale of transportation fuels; it raises fuel prices, discouraging vehicle travel, and encouraging the use of cleaner vehicles (such as electric vehicles (EVs)) and alternative modes of transportation (such as public transit). States with in-state refineries could apply a carbon price on the production of fuels; however, for states such as Maryland, which has no refineries, the most suitable place to apply a carbon price will likely be on fuel distributors who import the fuels into the state to supply retailers and fleet operators.

The emission profile provides a clear view of the sectors most impacted by a carbon price: transportation, electricity use, fuel use, industry (including fossil-fuel industry), and waste management.

EMISSIONS INCLUDED IN MARYLAND'S INVENTORY

Maryland's GHG inventory was included in the GGRA. It is a standard methodology that includes the emissions that occur within the borders of Maryland. An example of how the Port of Baltimore would be considered is summarized below:

Mining: Coal mined outside of Maryland is **not** included in Maryland's inventory and is included in the inventory of the mining state.

Transportation: The portion of transportation that occurs within Maryland's border is included in the inventory.

Port operations: Emissions to maintain the port function **are** included in Maryland's inventory.

Ships: Ships are included under international law and **not** included in Maryland's inventory.

End use: The end use of the coal is accounted for in the jurisdiction where it is burned.

SECTION 2: CARBON PRICING DESIGN OPTIONS

The context laid out above will likely help inform the decision on which carbon price instrument to use and the design elements that could be considered. In this section, the broader decisions to potentially be made within the design of a CPI are laid out. However, not all these design decisions are explicitly included within the analysis discussed in Section 3.

There are seven primary CPI design considerations outlined below. The first four were included in the quantitative analysis, whereas the last three were not.

1. The *type of instrument* decides whether a carbon tax, cap-and-trade, or crediting system is used.
2. The *scope* includes the industries covered. It also considers the gases and points of regulation, and these are considered in the analysis.
3. The *ambition* indicates the target of the carbon price.
4. *Competitiveness* determines how the instrument accounts for carbon leakage. Other competitiveness policies were not included in the analysis.
5. The *use of revenue* chooses how money raised will be spent.
6. *Offsets* can be included as a compliance option.
7. The *capacity* dictates what systems are required to implement the carbon price.

This section unpacks each design consideration in turn, covering the following:

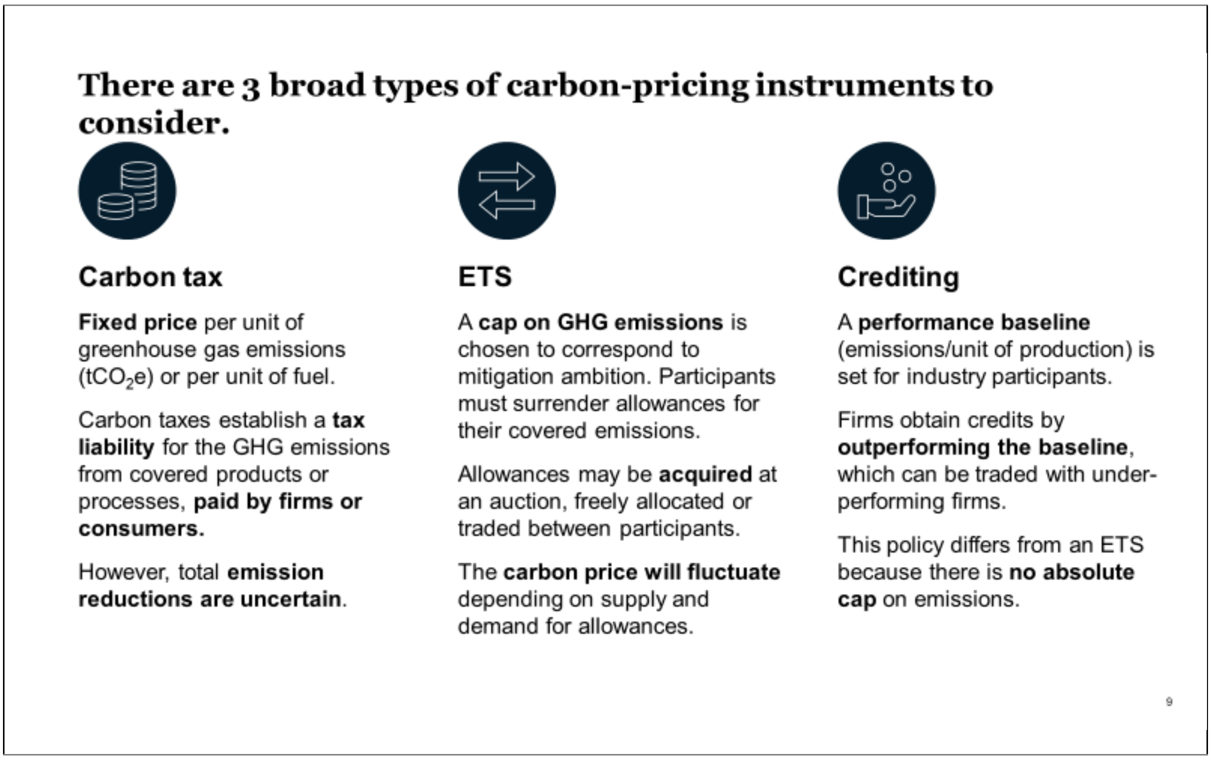
- the importance of the design consideration to build an effective CPI
- the options available to Maryland, given its context
- the decisions made to inform the quantitative analysis in Section 3 of this report

Type of carbon pricing instrument

A CPI aims to internalize the social cost of GHG emissions and thereby correct a “market failure.” Under a CPI, the price of carbon is mandated, and companies must pay for what they emit, typically in terms of CO_2e. If the price is sufficiently high, firms can be incentivized to reduce those emissions through cost-effective strategies. If it is too low, companies may decide to continue emitting and incur the cost of the carbon price. More cost-efficient reduction strategies are prioritized by companies, whereas those that are greater than the cost of carbon is not (Doda & Fankhauser, 2019). Previous studies have suggested that this flexibility leads to greater cost efficiency compared to “command-and-control” regulations (Best, Burke, & Jotzo, 2020).

Authorities can consider three broad mechanisms to price carbon: a carbon tax, a cap-and-trade system (also often referred to as an emissions trading scheme, or ETS), or a baseline and crediting system. The key features of each option are summarized in Exhibit 7 below.

Exhibit 7



There are 3 broad types of carbon-pricing instruments to consider.

Carbon tax

Fixed price per unit of greenhouse gas emissions (tCO_2e) or per unit of fuel.

Carbon taxes establish a **tax liability** for the GHG emissions from covered products or processes, **paid by firms or consumers.**

However, total **emission reductions are uncertain**.

ETS

A **cap on GHG emissions** is chosen to correspond to mitigation ambition. Participants must surrender allowances for their covered emissions.

Allowances may be **acquired** at an auction, freely allocated or traded between participants.

The **carbon price will fluctuate** depending on supply and demand for allowances.

Crediting

A **performance baseline** (emissions/unit of production) is set for industry participants.

Firms obtain credits by **outperforming the baseline**, which can be traded with under-performing firms.

This policy differs from an ETS because there is **no absolute cap** on emissions.

This analysis focuses on a carbon tax and a cap-and-trade system. Given Maryland's emission profile, where emissions are concentrated in sectors such as transportation and electricity generation, a baseline and crediting mechanism would likely not provide sufficient coverage across the Maryland economy. There may also be limited liquidity to trade credits in industries where there are limited in-state facilities. For example, cement manufacturing in Maryland has only two facilities—LeHigh and Holcim—with emissions high enough to be included in the 2017 GHG inventory.[10] This system would likely be most suitable in jurisdictions where there are vast competing stationary facilities, such as cement manufacturing and steelworks. Baselines could be established at each facility, and future performance can then be benchmarked against those baselines.

A carbon tax establishes a direct link between emissions and the tax that must be paid on them. This provides a stable price on which businesses can base their investment decisions to reduce emissions. However, while estimates of GHG emission reductions can be made, there is no guarantee of how the market will respond to the tax, therefore it is harder to predict ex-ante what the emission reductions will be.

A cap-and-trade system, such as the mechanism that is in place for the RGGI, places a hard cap on the amount of GHG emissions. Entities that are included under the scheme are required to hold one certificate for each unit of emission. The price they will have to pay for these certificates is determined by the market and could significantly fluctuate year over year.

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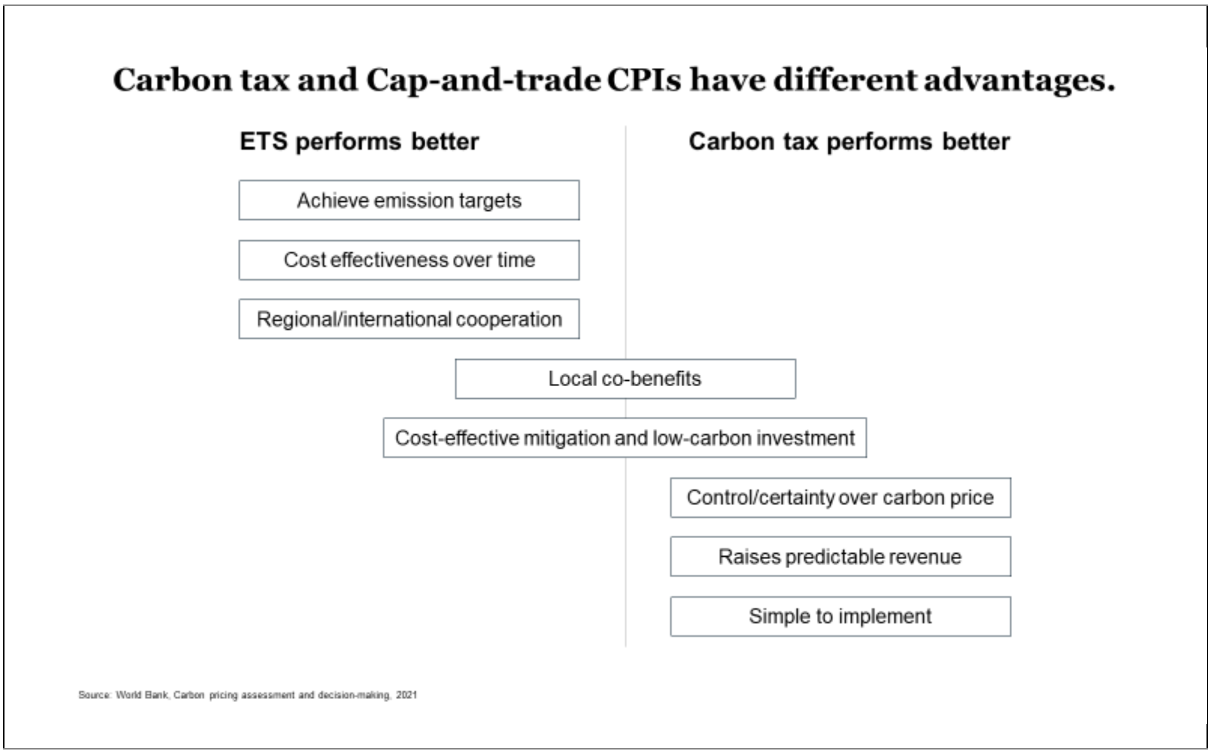
[10] Maryland Department of Environment, 2017 GHG Inventory.

Deciding between a carbon tax and a cap-and-trade system depends on what the CPI aims to achieve, and which may be better suited to Maryland's context and profile. Each has its advantages and performs better in some areas than others (Exhibit 8).

Exhibit 8



Carbon tax and Cap-and-trade CPIs have different advantages.

ETS performs better

Carbon tax performs better

Achieve emission targets

Cost effectiveness over time

Regional/international cooperation

Local co-benefits

Cost-effective mitigation and low-carbon investment

Control/certainty over carbon price

Raises predictable revenue

Simple to implement

Source: World Bank, Carbon pricing assessment and decision-making, 2021

This report used the carbon-tax tool in its analysis for the following three primary reasons:

- **Scale of coverage:** A cap-and-trade system requires there to be a liquid market, and a market the size of Maryland may have insufficient liquidity to enable an efficient market operation.
- **Ease of implementation:** While a trading system is in place for the RGGI, instituting a cap-and-trade system would likely require Maryland to build up its own capacity to establish and run a statewide trading system.
- **Predictable revenue:** A carbon tax will generate a stable revenue stream that the State of Maryland may consider for strategic investments or to compensate companies and residents for energy-price increases.

Scope

The scope of a carbon tax defines the sources of GHG emissions that are regulated by the carbon price. This encompasses the following four separate elements:

- sectors—deciding which parts of the economy will be covered
- threshold—defining sources of emissions too small to include because of the administrative costs of their inclusion

- GHGs—excluding any of the six major GHGs (CO2, methane, nitrous oxide, chlorofluorocarbon-12, hydrofluorocarbon-23, and sulfur hexafluoride) from the carbon price
- point of regulation—assigning responsibility to pay the carbon price within each sector's value chain, such as upstream, midstream, or downstream

Sectors

Across each of these aspects, deciding the scope depends on the main sources of emissions, the climate policy landscape, and the capacity of participants to comply with the CPI. It can be narrow and focused—such as RGGI, which is limited to large power-generation facilities—or economy-wide, such as Canada's federal fuel charge.

The agricultural and land-use sectors are rarely covered by carbon pricing because of they are small and heterogenous entities with limited monitoring, reporting, and verification (MRV) capabilities. Therefore agriculture, which only accounts for 2 percent of state emissions (see Exhibit 6), and land use, which is a carbon sink, are excluded from the analysis in Section 3. However, the following five core sectors, which account for 98 percent of Maryland's emissions, are included in the quantitative analysis: transportation; power; residential, commercial, and industrial fuel use; industrial processes (including the fossil fuel industry); and waste management.

Threshold

The initial quantitative analysis in this report has not included threshold, GHG coverage, or the point of regulation, although they remain important elements**.** For large and static sources of emissions, a threshold size may be beneficial, as it reduces administrative costs, while still covering the majority of emissions. For example, a decision may be taken to exclude diesel generators, as their emission scope is small and the administrative complexity of including them—for both the state and the business—may exceed the benefit of any potential emission reductions.

GHGs

GHG coverage is related to the choice of sectors, but may be limited by MRV capabilities. The marginal abatement cost curves (MACCs) used in the analysis include CO2, methane, hydrofluorocarbons (HFCs), and nitrous oxide, which contribute to over 95% of the emissions in Maryland.[11]

Point of regulation

Finally, the ideal point of regulation is where emissions can be accurately monitored, and compliance enforced. Ideally, this occurs where the emissions are created by a few major players to simplify administration. The optimal point of regulation varies across Maryland's main sectors (Exhibit 9).

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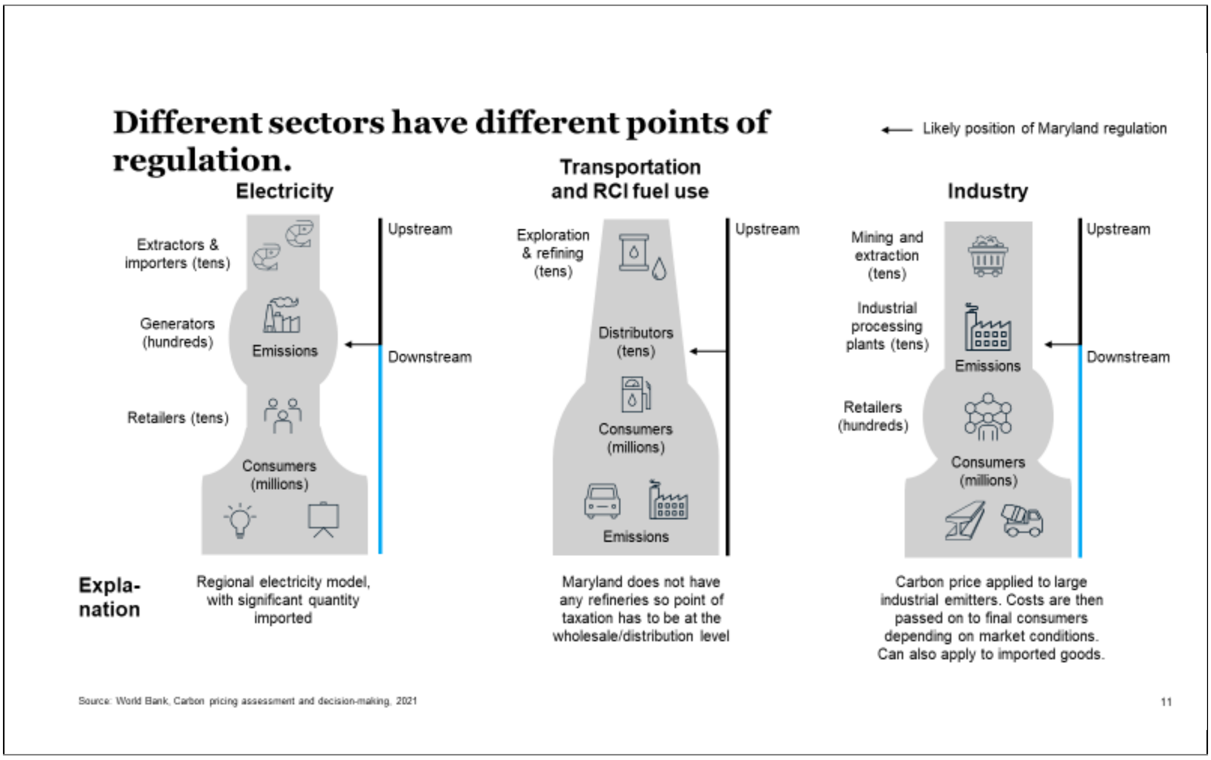
[11] Based on 2017 emissions from Maryland GHG inventory. Excludes HFCs, which are grouped with PFCs and SF_6 in GHG Inventory meaning the actual figure may be higher.

Exhibit 9



Different sectors have different points of regulation.

← Likely position of Maryland regulation

Expla- nation	Regional electricity model, with significant quantity imported	Maryland does not have any refineries so point of taxation has to be at the wholesale/distribution level	Carbon price applied to large industrial emitters. Costs are then passed on to final consumers depending on market conditions. Can also apply to imported goods.

Source: World Bank, Carbon pricing assessment and decision-making, 2021

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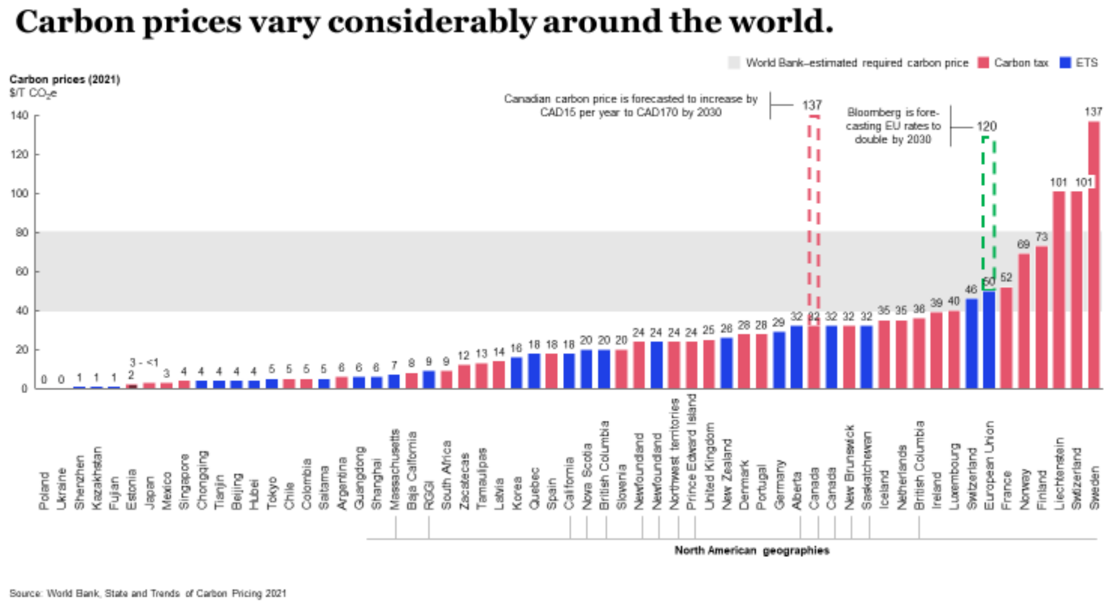
Intent

The price level of a carbon pricing instrument determines the strength of the abatement incentive. A higher tax level implies an aggressive posture and greater emission reductions. By contrast, a lower tax level implies a less aggressive posture, with lower costs. In practice, because emission reductions are uncertain and because taxes have a propensity to be frozen, setting an appropriate carbon tax level can be challenging.

Carbon prices vary considerably around the world, but the majority are below the World Bank’s minimum recommended level of $40 per metric ton (High-level Commission on Carbon Prices, 2017). As of June 2021, RGGI prices stood at $7.97 per short ton—equivalent to $7.23 per metric ton, compared to $32 per metric ton in Canada, and $50 per metric ton in the European Union ETS (Exhibit 10). It is common for carbon prices to increase with time; for example, the Canadian federal fuel charge is set to increase by CAD 15 each year to CAD 170 by 2030.

Exhibit 10



Carbon prices vary considerably around the world.

Source: World Bank, State and Trends of Carbon Pricing 2021

The analysis in Section 3 includes carbon prices of $40, $60, and $80 per metric ton. An optimal carbon price was not derived to reach a specific goal, such as the proposed GGRA 2030 target of 50 percent below 2006 levels. Rather, a range of carbon prices recommended by the World Bank acted as a guide (High-level Commission on Carbon Prices, 2017). Choosing an appropriate carbon price is a complex process, and a price outside the studied range could also be considered. To illustrate the effect of increasing ambition over time, an illustrative 5 percent annual increase is included, consistent with other carbon prices established throughout the world.

Competitiveness

Applying a carbon price unilaterally in a single state could create the potential for carbon leakage. Carbon leakage occurs when an emission-reduction policy in one jurisdiction causes an increase in emissions in other jurisdictions with weaker climate policies. Leakage may arise, for example, from local firms shifting the location of production outside the state, or locally made commodities being replaced by cheaper imports.

However, Maryland has a range of established strategies to potentially choose from to reduce the risk of carbon leakage, such as tax exemptions and reduced rates or carbon-border adjustments (CBA). Excluding industries at risk of carbon leakage from the carbon price, while simple to implement, could reduce overall mitigation and revenues. It also risks political challenges related to the *polluters pay* principle. In some jurisdictions, such as Switzerland, tax exemptions are contingent on firms entering into legally binding emission-reduction agreements. Although this approach still reduces revenues, it maintains the abatement incentive.

CBA measures present challenging options for a state such as Maryland owing to the lack of a customs border, potential administrative costs, and political considerations. However, there may be some precedent for states to include imports in their carbon pricing policy, where practical. California includes imported electricity and transportation fuels in its cap-and-trade program.[12]

The use of carbon pricing revenues may also be effective at reducing competitiveness effects and preserving employment within specific industries. For example, recycling revenue in the form of lump-sum rebates compensates businesses for additional costs incurred, while maintaining the carbon price signal. Firms are still incentivized to reduce their net carbon-tax payments by reducing emissions.

However, rebates can be made more effective as part of an output-based rebating system. This would likely allow more efficient firms within an industry to benefit from a rebate and could boost production relative to inefficient competitors. Such a system could allow employment losses at less efficient facilities to be potentially canceled out by increased employment at more efficient competitors.

Similarly, feebates (a self-financing system of fees and rebates), where revenue is raised from the most emission-intensive businesses and returned to more efficient businesses, are a revenue-neutral way of maintaining abatement incentives without adversely impacting economic productivity.

Carbon tax revenues could also be considered to reduce other taxes on businesses—such as corporate income tax—possibly creating a "double dividend" of economic growth and climate mitigation. Tax reform is most effective at reducing carbon leakage if at-risk sectors face specific taxes —for example, a tax on electricity production (Pigato, 2019). Finally, subsidies and technical assistance can be an option to consider for firms to potentially increase the adoption of low-carbon technologies and overcome financial barriers to adoption.

The quantitative analysis in this report incorporates measures to protect competitiveness and prevent carbon leakage. The economic analysis includes a scenario in which a 30 percent tax rebate is offered to manufacturing and industrial firms —covered by the carbon tax—to compensate them for the additional costs that result from implementing the CPI. However, although this scenario is easy to assess, it is only one potential approach within the broad spectrum of competitiveness options that are available to Maryland. Other options could be more effective at reducing the effects of competitiveness and preserving employment within specific industries—for example, in the output-based rebating system discussed above.

Maryland could consider which options represent the most efficient use of revenue, while at the same time retaining the abatement incentive and mitigating the risk of carbon leakage, for example. A specific comparison of all the potential options in the Maryland context is beyond the scope of the initial quantitative analysis in this report. However, as mentioned above, imported electricity from other states is included under the carbon tax to address specific competitiveness concerns about Maryland's electricity. This means that all electricity used by Maryland consumers is treated equally under the program.

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[12] California Air Resources Board (CARB).

Use of revenue

Carbon revenue can either be allocated to general government revenue or be tied to specific purposes. The way it is used can affect the scale of impact of the carbon tax. Tying carbon revenue to a particular use could provide greater visibility of the link between carbon pricing and public services, whereas directing it into the general fiscal pool could allow for greater flexibility to alter revenue uses as circumstances and priorities change. If used wisely and communicated effectively, carbon revenue could support further climate mitigation, industry competitiveness, and other economic objectives, as well as potentially improve public acceptance of the CPI.

Revenue could be used to support low-income households affected by increased energy prices associated with the carbon tax—for example, to compensate those affected through direct cash transfers, subsidies, or support for retraining. It could also be used to mitigate the impact of carbon prices on competitiveness in the short term. There are various instruments that may reduce the chance of shifting production to uncovered markets by enabling firms to adjust their business models in the short term. Examples of these include feebates where revenue is collected from the most emission-intensive businesses and returned to more energy-efficient businesses based on a chosen “pivot point” (the “pivot point” is determined by using a benchmark of efficiency for that industry—either Maryland-specific or US-wide). Other examples include output-based methods, which provide tax rebates for facilities below a sector-specific benchmark.

Carbon revenue could finance additional policies or programs aimed at reducing emissions. This may enhance the impact of climate policies by combining a price signal with targeted spending. Spending revenue on further climate mitigation is often used to overcome financial barriers to investment, such as through green investment banks, to address incomplete information—for example, in the introduction of smart meters—or to unlock abatement opportunities that rely on networks by lowering the overall costs of mitigation options.[13] An example of the latter is public EV charging infrastructure.

The analysis in Section 3 considers illustrative uses of revenues. However, these uses are not a recommendation; other options may be more effective and further analysis would be required before reaching a final decision on allocating revenue.

Offsets

Offsets provide regulated entities with flexibility. Carbon pricing can provide the option to regulated entities to use “carbon credits”—or offsets—to meet a portion of their compliance requirements through the establishment of a crediting mechanism. The offsets lower the tax exposure of a business by lowering its effective emissions through investment in a program that sequesters some carbon. This often reduces the costs to covered entities but could also reduce the total revenue collected by the state.[14] A carbon price in Maryland could be considered to potentially incentivize emission reductions or increased sequestration in priority sectors—such as wetlands

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[13] Matthew J Kotchen, Zachary M Turk, & Anthony A Leiserowitz, “Public willingness to pay for a US carbon tax and preferences for spending the revenue,” 2017.

[14] Where the cost of offsetting is lower than the carbon price.

conservation in the Chesapeake Bay, where a sediment-trading program administered by the U.S. Environmental Protection Agency is already in place.[15]

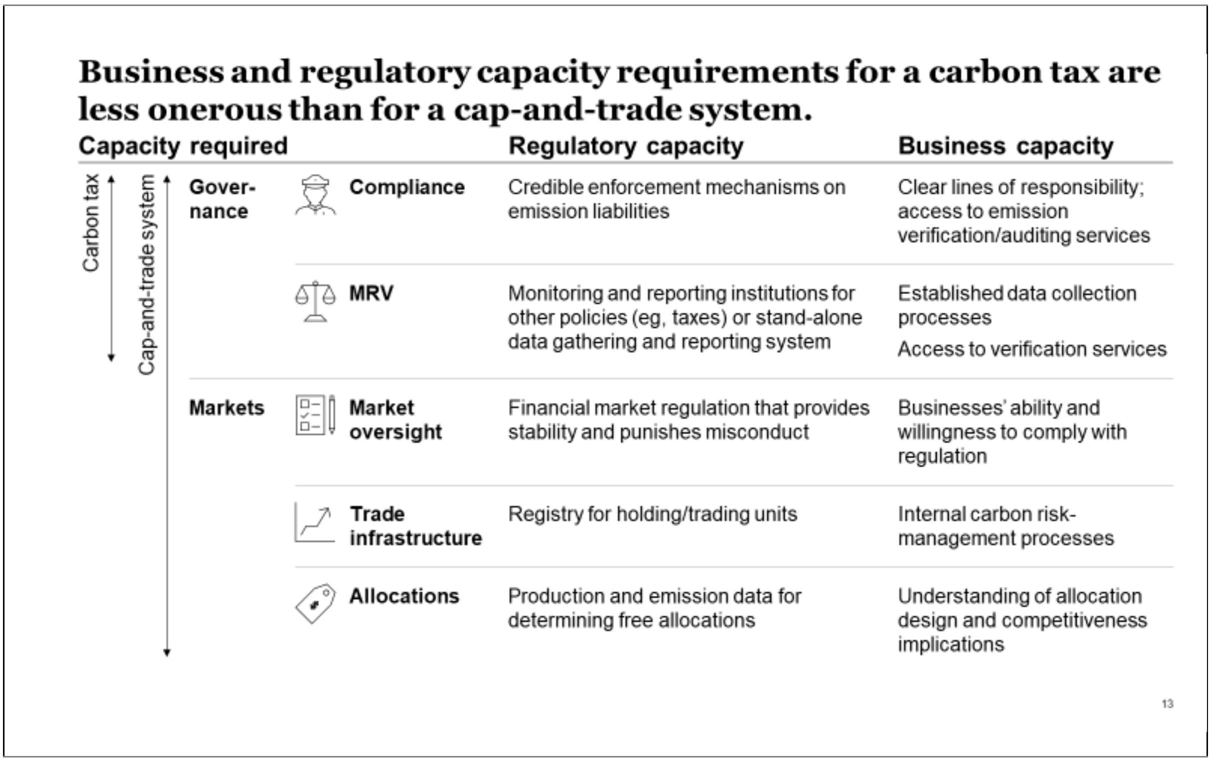
In designing a carbon tax, a strategic decision is likely required about whether offsets should be included and how they will be verified. Maryland could administer offsets in a similar way to that in which the RGGI administers its offset protocols, or through a third party, such as in the case of California's cap-and-trade program. Should Maryland decide on the former, it may require additional administrative capacity to ensure that offset protocols and verification procedures are implemented correctly by project developers.

This report does not consider offsets as part of the carbon tax scenarios.

Capacity

It can take significant time to build the capacity needed to support effective carbon markets. One reason why Maryland may decide not to consider a cap-and-trade system is the extensive government and business capacity needed to operate and regulate the market (Exhibit 11). In contrast, a carbon tax could be implemented and operated using existing systems established for measuring GHG emissions and collecting taxes or fees. In designing a carbon tax, governments will likely want to assess the legal and institutional factors required to implement a CPI, as well as its economic and political feasibility.

Exhibit 11



Business and regulatory capacity requirements for a carbon tax are less onerous than for a cap-and-trade system.

Capacity required		Regulatory capacity	Business capacity
Gover-nance	**Compliance**	Credible enforcement mechanisms on emission liabilities	Clear lines of responsibility; access to emission verification/auditing services
	MRV	Monitoring and reporting institutions for other policies (eg, taxes) or stand-alone data gathering and reporting system	Established data collection processes Access to verification services
Markets	**Market oversight**	Financial market regulation that provides stability and punishes misconduct	Businesses' ability and willingness to comply with regulation
	Trade infrastructure	Registry for holding/trading units	Internal carbon risk-management processes
	Allocations	Production and emission data for determining free allocations	Understanding of allocation design and competitiveness implications

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[15] The Chesapeake Bay Total Maximum Daily Load (TMDL) sets a limit on nitrogen, sediment and phosphorus pollution. As in a cap-and-trade program, regulated entities can trade pollution credits to remain under the TMDL cap. See cbf.org.

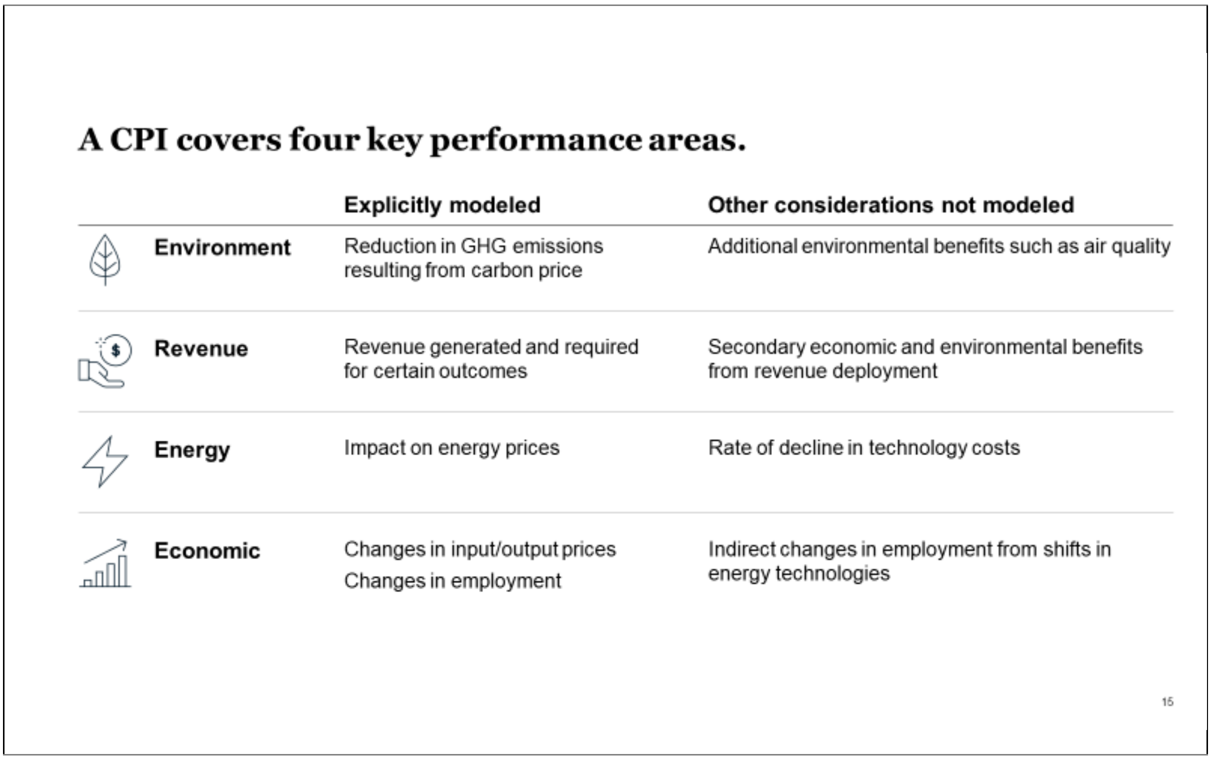
Should Maryland give serious consideration to implementing a carbon tax, it will be necessary to consider a particular focus on building capabilities around compliance and MRV that ensure credible enforcement mechanisms on emission liabilities, as well as robust monitoring and reporting activities.

Although Maryland's capacity is not evaluated as part of the quantitative analysis, the new capacities required to make a carbon price function effectively could be discussed with key stakeholders such as the Maryland legislature and relevant state agencies.

SECTION 3: QUANTITATIVE ANALYSIS AND ANALYTICAL RESULTS

The report includes a quantitative analysis designed to provide initial insights into the impacts of a carbon price in Maryland. The approach provided results focused on indicators in four key performance areas: environment, revenue, energy, and economy (Exhibit 12).

Exhibit 12



A CPI covers four key performance areas.

	Explicitly modeled	Other considerations not modeled
Environment	Reduction in GHG emissions resulting from carbon price	Additional environmental benefits such as air quality
Revenue	Revenue generated and required for certain outcomes	Secondary economic and environmental benefits from revenue deployment
Energy	Impact on energy prices	Rate of decline in technology costs
Economic	Changes in input/output prices Changes in employment	Indirect changes in employment from shifts in energy technologies

Scenario definition

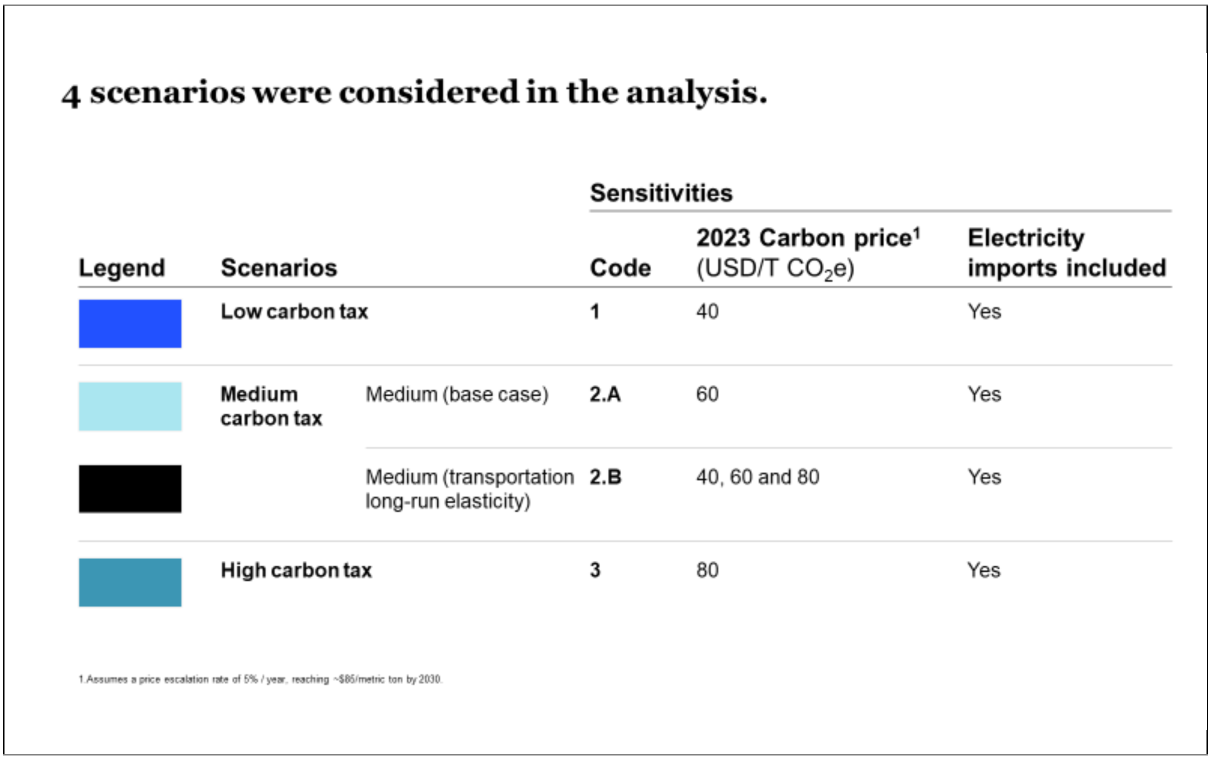
Based on the considerations described above, the quantitative analysis in Section 3 includes five scenarios, which all share the following parameters:

- **Land use and agriculture are excluded:** These are complex industries to model and, in the case of agriculture, are relatively small in terms of GHG emissions.
- **Offsets are not included:** While this is a key design choice, the analysis makes the simplifying assumption that firms are unable to use offsets. The inclusion of offsets would not affect net emissions but may affect where those emissions occur and delay the decarbonization of the industrial sector.
- **The economic impacts of revenue recycling are not estimated:** The quantitative analysis calculates how much will be generated   and the investment needed for specific uses but does not include second-order impacts from spending the revenue.
- **Assumed implementation is January 1, 2023:** The analysis makes the simplifying assumption that the carbon price is implemented at the start of

2023, and that there is no ramp-up period to the stated starting carbon price—$40, $60, and $80 per metric ton CO_2e.

The quantitative analysis centers on a base case, scenario 2A, which assumes that a carbon tax of $60 per metric ton CO_2e is applied to all core sectors and electricity imports. To illustrate the effect of the carbon price, scenario 1 illustrates a low-carbon tax case—at $40 per metric ton—and scenario 3 provides a high carbon tax case, at $80 per metric ton (Exhibit 13). The analysis also considered additional cases, scenarios 2B, which is further explained in later sections.

Exhibit 13



4 scenarios were considered in the analysis.

			Sensitivities		
Legend	**Scenarios**		**Code**	**2023 Carbon price**[1] (USD/T CO_2e)	**Electricity imports included**
🟦	**Low carbon tax**		**1**	40	Yes
🟦	**Medium carbon tax**	Medium (base case)	**2.A**	60	Yes
⬛		Medium (transportation long-run elasticity)	**2.B**	40, 60 and 80	Yes
🟦	**High carbon tax**		**3**	80	Yes

1.Assumes a price escalation rate of 5% / year, reaching ~$85/metric ton by 2030.

All these scenarios include an annual escalation of 5 percent. Table 2 below illustrates the impact on the carbon price by 2031 in scenarios 1, 2 and 3:

Table 2: Carbon Price Escalation with a 5% Annual Increase, 2023–2031, $/Metric Ton CO_2E

	2023	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**
Scenario 1	40	42	44	46	49	51	54	56	59
Scenarios 2A, 2B	60	63	66	69	73	77	80	84	89
Scenario 3	80	84	88	93	97	102	107	113	118

Key takeaways

This report represents a first step in understanding the potential role of carbon pricing in Maryland. It is a policy option that could form a part of Maryland's strategy to meet the goals laid out under the GGRA.

Based on the initial analysis, takeaways for Maryland policymakers to consider include the following:

- **A carbon price could be a feasible option in Maryland's context.** The predominance of services in the Maryland economy and a smaller industrial base could affect how policymakers design a carbon price.
- **A carbon price could be designed to meet the existing GGRA emission target of 40 percent below 2006 levels by 2030.** However, meeting the proposed 50 percent reduction target may be unlikely within the range of carbon prices analyzed in this report. A higher carbon price could enhance mitigation efforts. Alternatively, policymakers could enact new policy measures in sectors such as agriculture and land sequestration, which were not covered by a carbon price in this analysis.
- **Carbon pricing is a policy option that can be considered alongside complementary policies.** For example, the carbon price could enhance mitigation efforts in the power sector, but unlocking broader transformation, such as vehicle electrification, could require a suite of incentives and infrastructure deployment not directly incentivized by a carbon price.
- **Maryland could use carbon pricing revenue to enhance policy priorities.** This analysis indicates that energy assistance to low- and middle-income households, a tax rebate for industrial firms, investments in clean energy, and restoring natural lands in the Chesapeake Bay are viable options for using revenue generated by a carbon price. A broader household rebate of approximately $900 could generate a net-positive impact on employment. However, Maryland policymakers are not limited to these options.

These key results are explained in greater detail below. A detailed explanation of the methodology used for the quantitative analysis is included in the Appendix.

Scenario outcomes

This analysis compares the potential impact of a carbon price across scenarios. The table below summarizes the key results for the base-case scenario and alternative carbon price levels, which are explained in greater detail below. The sensitivity (scenario 2B) is also explained later in this section.

TABLE 3: Overview of Results for Scenarios 1, 2A, and 3

	Scenario 1	Scenario 2A	Scenario 3
2023 carbon price (\$/ metric ton of CO_2e)	40	60	80
Emission reduction in 2031 (%) relative to reference scenario	4%	7%	9%
2030 gross emissions (MMT CO_2e)	63.4	63.1	61.3
GGRA emission reduction target achieved	40% by 2030	40% by 2030	40% by 2030
Monthly electricity price increase in 2023 (\$)	13	20	27
Change in manufacturing/industry output in 2023 (%)	-3.6%	-5.4%	-7.1%
Change in manufacturing/industry employment (FTEs) in 2023	-2,003	-2,995	-3,979

Effect of price level on emission reduction

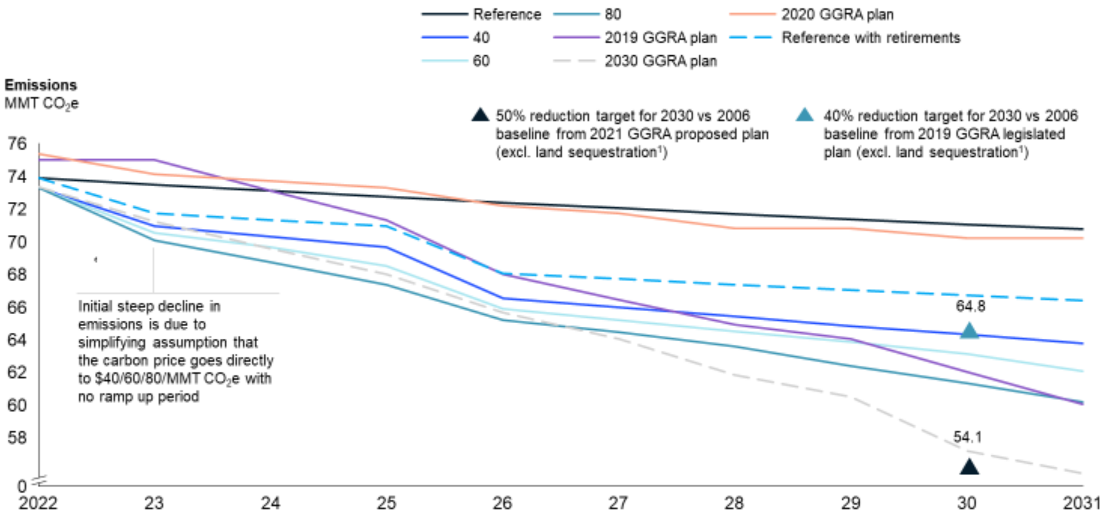
Establishing a carbon price may significantly reduce Maryland’s GHG emissions over time and play an important role in supporting Maryland’s 2030 emission targets. However, the potential emission reduction of a carbon tax is highly dependent on the chosen price level. Exhibit 14 and table 3 above summarize the emission reductions associated with the three different carbon prices considered in our analysis. (For clarity, “Reference with retirements” is the baseline used in this analysis. “2020 GGRA Plan” is the reference scenario under the GGRA Draft plan. “2019 GGRA Plan” refers to policies proposed under the 2019 GGRA draft plan. “2030 GGRA Plan” refers to policies proposed under the 2030 GGRA draft plan released in February 2021.)

Scenario 1’s $40 per metric ton carbon tax could enable Maryland to reach the 2016 GGRA’s 40 percent gross emission reduction target by 2030. At this price level, Maryland could thus meet its mitigation goals without additional climate policies, other than the current RGGI and RPS requirements, assuming the coal retirements occur.

The results of scenario 3 suggest that a carbon tax of $80 per metric ton would be insufficient to reach the 50 percent emission-reduction target proposed in the 2030 GGRA plan. However, when coupled with an enabling policy environment and additional climate measures in uncovered sectors, an $80 per metric ton carbon tax could enable Maryland to reach its proposed target.

Exhibit 14

GHG reduction is dependent on the chosen carbon-price level.



1.Land sequestration was excluded as only gross emissions are considered. The increase in targets reflects an additional 11.8Mt CO_2 from sequestered land.
Projected emissions taken from the 2030 GGRA reference scenario

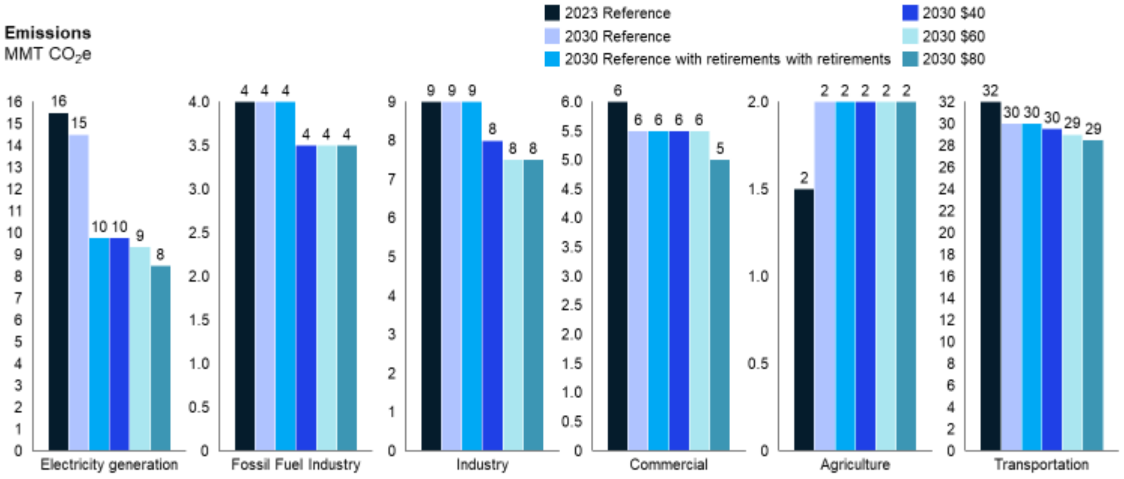
Source: Enerdata; Maryland DoE GGRA plan 2030

Emission reduction by sector

The carbon tax could reduce emissions across all covered sectors, with electricity generation experiencing the most marked difference between the different carbon price scenarios. Under scenario 2A, electricity emissions in 2030 would be 4 percent lower than in the reference scenario (Exhibit 15), but 13% lower under scenario 3. Industry emissions would likely be the next most affected sector, with 2030 emissions 15 percent lower than in the reference scenario. In contrast, transportation emissions experience a weak decline compared to the reference under scenario 2A, with 2030 emissions only 4 percent lower than the reference scenario. Even under the highest carbon tax in scenario 3, 2030 transportation emissions only decrease by 6 percent compared to the reference scenario. However, the MACC for transportation assumes short-run price elasticities, where consumers react to changes in price by changing their driving habits—for example, by driving less. The emission-reduction impact could be higher if long-run price elasticities prevail (see next section).

Exhibit 15

Electricity generation and industry sectors would likely experience the largest proportional decline in emissions.



Source: Enerdata; Maryland DoE GGRA plan 2030

Sensitivity: scenario 2B's long-run transportation elasticities

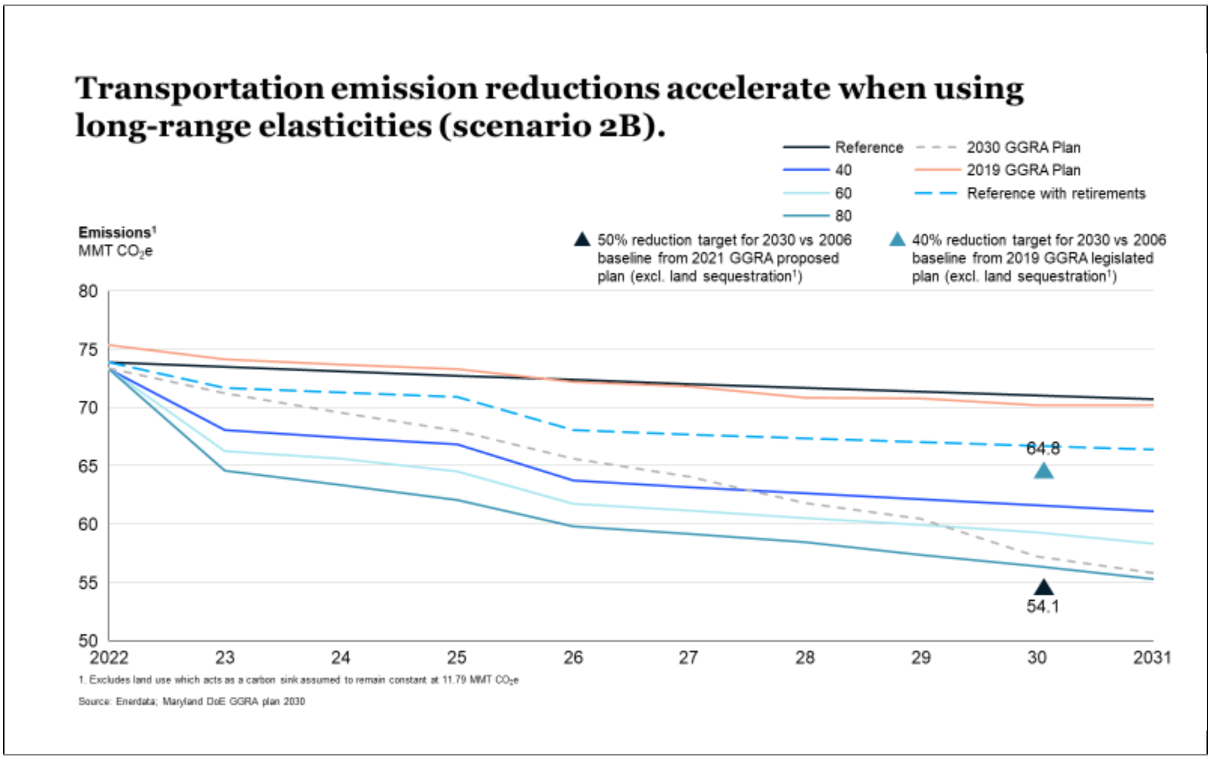
In the context of transportation, a long-run price elasticity translates into drivers reacting to a consistent price change by making more dramatic changes to their behavior. This could include larger cuts to their driving such as commuting on public transportation, purchasing a more efficient car, or transitioning to a plug-in hybrid or zero-emission vehicle. Academic studies show that a short-run change in demand would be −0.249, meaning that, if fuel prices increase by 100 percent, gasoline demand declines by 24.9 percent. However, a long-run elasticity would generate a 72.0 percent decline (Labandeira, Labeaga, & López-Otero, 2016).

To demonstrate the range of emission-reduction potential in transportation, scenarios with short-run (scenario 2A) and long-run (scenario 2B) price elasticities are included. The transportation sector is a focus because it is Maryland's largest source of GHG emissions, and the difference between short- and long-run price elasticities is large.

Using long-run elasticities to capture a switch toward EVs accelerates the decline in transportation emissions across the low, medium, and high carbon tax scenarios (Exhibit 16). Under the $60 per metric ton carbon price, transportation emissions in 2030 would be 6 percent lower than when using short-run elasticities (scenario 2A). Including long-range elasticities also means that the 2030 GGRA Plan's 50 percent reduction target is within reach under the $80 per metric ton carbon price.

Accompanying a carbon price with a broader suite of incentives and investments such as EV charging infrastructure or rebates for vehicle purchases could encourage consumers to make longer-term decisions such as switching from an internal combustion engine vehicle to an electric alternative.

Exhibit 16



Transportation emission reductions accelerate when using long-range elasticities (scenario 2B).

1. Excludes land use which acts as a carbon sink assumed to remain constant at 11.79 MMT CO_2e

Source: Enerdata; Maryland DoE GGRA plan 2030

Alongside reducing GHG emissions, the shift towards greener technologies has two additional potential outcomes:

- **It could improve local air quality.** Pollutants from fossil-fuel combustion such as ozone, PM2.5, SO_x, and NO_x have significant health impacts and are linked to premature mortality. For example, according to a literature review of studies, the air-quality benefits of mitigation in developed countries range from \$2 to \$128 per metric ton of CO_2, with a median of \$31 per metric ton of CO_2 (Nemet, Holloway, & Meier, 2010).[16] This equates to \$39 in current dollars.
- **Increased renewable electricity production may reduce water use and improve water quality.** Fossil-fuel combustion power plants consume considerably more water than renewable electricity generation. The lifecycle water consumption of an average coal-fired power plant is 2,220 liters per MWh, compared to only 300 liters per MWh for solar PV and just 40 liters per MWh for wind (Jin, Behrens, Tukker, & Scherer, 2019). Consequently, Maryland's carbon tax may provide considerable water-use and quality benefits.

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[16] In 2008 US dollars, based on health benefits and avoided costs from not purchasing pollution-control equipment.

Revenue results

A carbon tax could provide a predictable source of government revenue. Carbon tax revenue can either be allocated to Maryland's general budget or targeted to specific uses. Common uses of revenue include compensation for firms or households, tax reforms or investment in further mitigation. In later sections of the report, further exploration of these options is included and consideration of some illustrative uses of revenue for Maryland is provided.

The amount of revenue raised is directly linked to Maryland's GHG emissions and the carbon price. Since the price is set explicitly and is not variable, the revenue collected from the carbon tax in each scenario is calculated by multiplying annual emissions in covered sectors by the carbon-tax rate. This analysis assumed a 5 percent annual increase in carbon price and, importantly, requires that a demand response to the carbon price be considered. A response, such as emission mitigation through technology adoption, fuel switching or behavioral changes, would likely reduce emissions and government revenue. This analysis does not include a threshold size, which would reduce the number of covered entities and hence also reduce revenues.

Across the carbon price ranges considered, Maryland could raise between \$2.8 billion and \$5.6 billion in the first year of the tax. In 2023, under scenario 2A, emissions in covered sectors would be 70 MMT CO2e.[17] At a \$60 per metric ton carbon price this would translate to ~\$4.25 billion in revenue—equivalent to 9 percent of Maryland's annual state budget (Exhibit 17).

Regardless of price, carbon-tax revenue would likely grow over time as the tax rate increases. In scenario 2A, revenue increases by ~27 percent by 2030, reaching \$5.4 billion. The increase is more pronounced for the lower carbon-tax rate (scenario 1)—at 28 percent—and less pronounced for the higher tax rate (scenario 3), at 22 percent.

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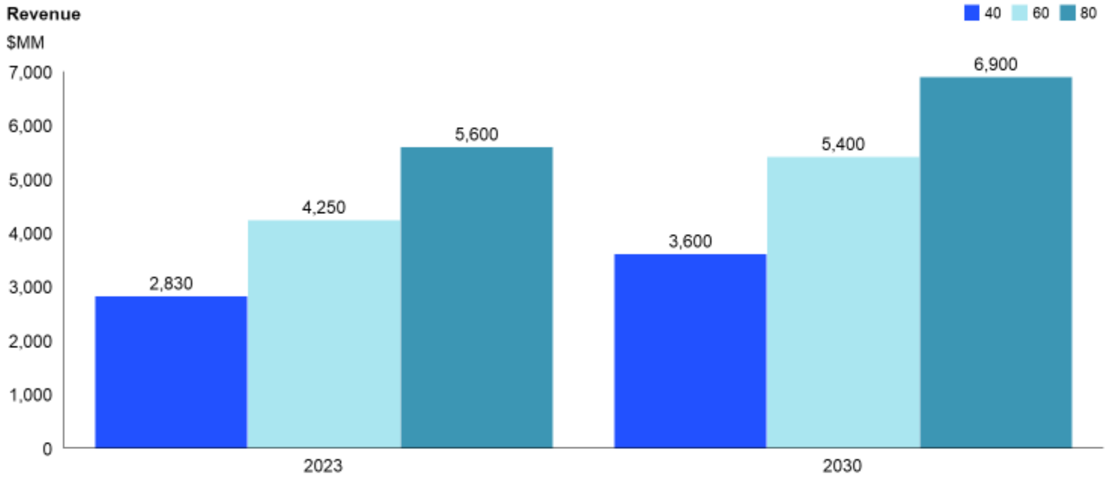
[17] Excludes agriculture responsible for 1.54 MMT CO_2e in 2023.

Exhibit 17

A carbon tax could raise between $2.8 billion and $5.6 billion in the first year.



1. Revenue is calculated by multiplying the in-year carbon price by the amount of forecasted emissions; this includes the 5% multiplier, so the carbon price that started at $80/ton in 2023 is equal to ~$113/ton

Source: Enerdata

The revenue generated under the carbon tax could serve multiple purposes. To illustrate this, the analysis includes 2023 cost estimates for four different potential uses under the base case scenario (2A).

1. A rebate to the lowest five deciles by household income for all additional energy costs incurred by the carbon tax ($444 million)
2. A uniform 30% tax rebate to all manufacturing and industry firms in Maryland ($690 million)
3. Investments in green technology that create jobs equal to employment changes in the manufacturing and industry sector. Recent research has suggested that different green technologies create different jobs per million invested. On the low end, creating approximately 5–6 jobs per $1 million invested, is investing in air conditioning units. In contrast, urban forestry and subsidizing municipal transit operations could create up to 16–23 jobs per $1 million. Depending on the mix of investments selected by Maryland, this would imply a cost of between $122 million and $1,159 million to offset the potential negative job impact of the carbon tax.[18]
4. Public investment in wetlands restoration in the Chesapeake Bay is equivalent to 1.5 million metric tons. Per-metric-ton costs for reducing emissions through wetlands restoration in the Chesapeake Bay are currently being studied by the Maryland Department of Natural Resources, so an estimated cost of $150 per metric ton is used.

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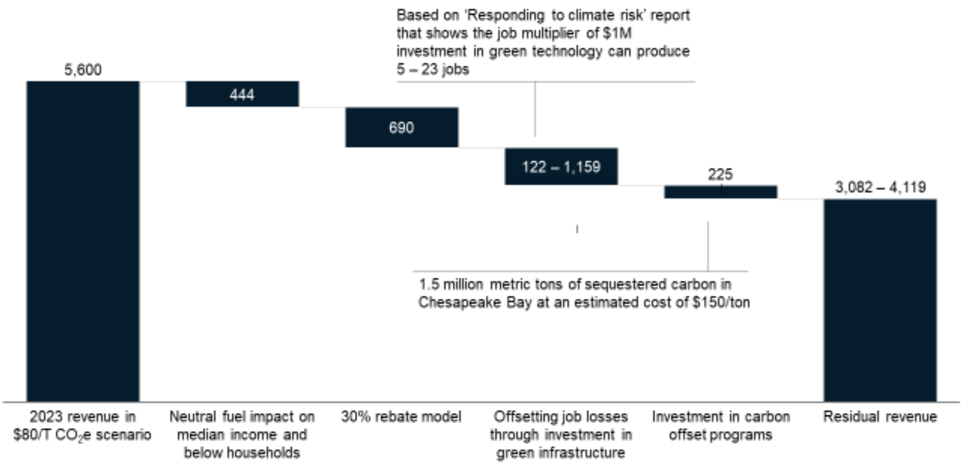
[18] Based on a study that shows the job multiplier of an investment of $1 million in green technology can generate between 5 and 23 jobs: https://www.mckinsey.com/business-functions/sustainability/our-insights/america-2021-renewing-the-nations-commitment-to-climate-action.

These do not represent the full breadth of options available to Maryland for the use of revenues, but instead illustrate the different categories of revenue use that a carbon tax could enable (see Exhibit 18).

Exhibit 18

Using carbon revenues for households, industry rebates, job investments and carbon offsets would still leave additional revenue for Maryland

USD $MM

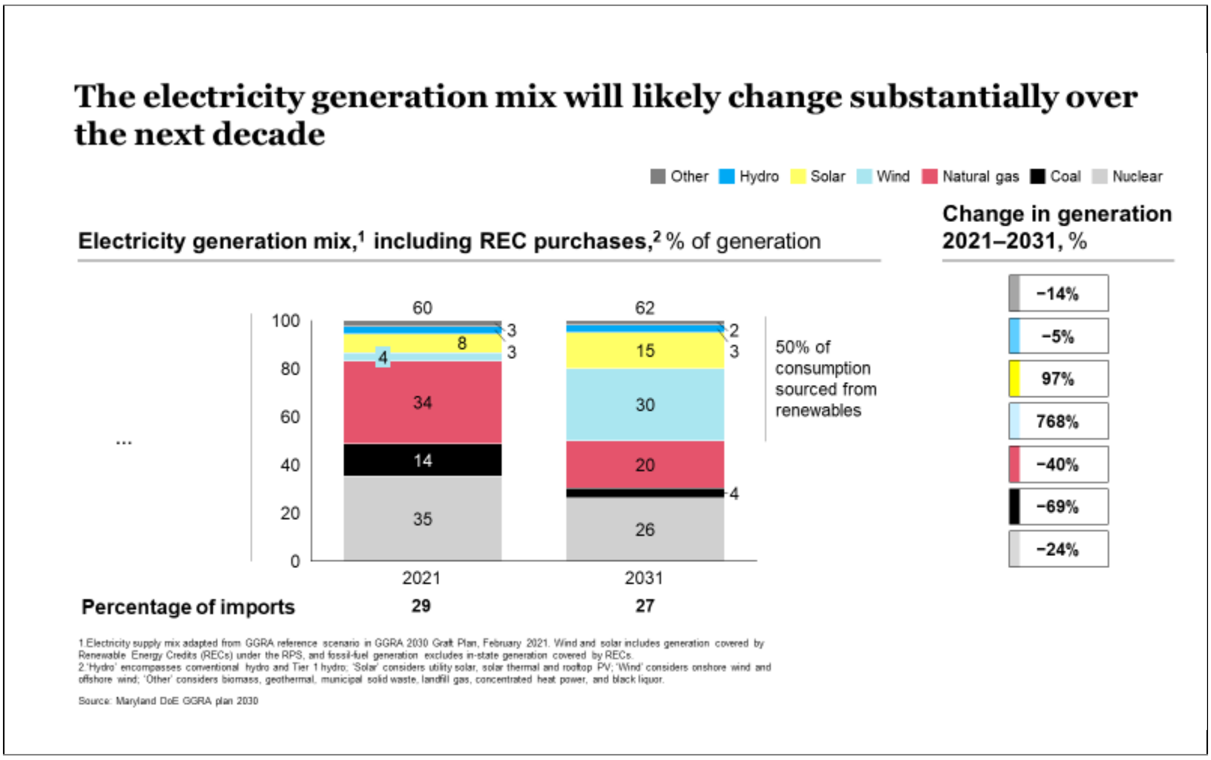


Source: Enerdata, McKinsey, February 2021 – Responding to climate risks. Actions for US state and local leaders, Chesapeake Bay Foundation

Energy results

The MACC analysis did not measure changes in the electricity mix but used the changes in the electricity mix projected under the GGRA 2030 reference scenario as a basis to estimate the additional capacity from fossil-fuel generation affected by the carbon price in 2031 (Exhibit 19).

Exhibit 19



The electricity generation mix will likely change substantially over the next decade

50% of consumption sourced from renewables

1.Electricity supply mix adapted from GGRA reference scenario in GGRA 2030 Graft Plan, February 2021. Wind and solar includes generation covered by Renewable Energy Credits (RECs) under the RPS, and fossil-fuel generation excludes in-state generation covered by RECs.

2.'Hydro' encompasses conventional hydro and Tier 1 hydro; 'Solar' considers utility solar, solar thermal and rooftop PV; 'Wind' considers onshore wind and offshore wind; 'Other' considers biomass, geothermal, municipal solid waste, landfill gas, concentrated heat power, and black liquor.

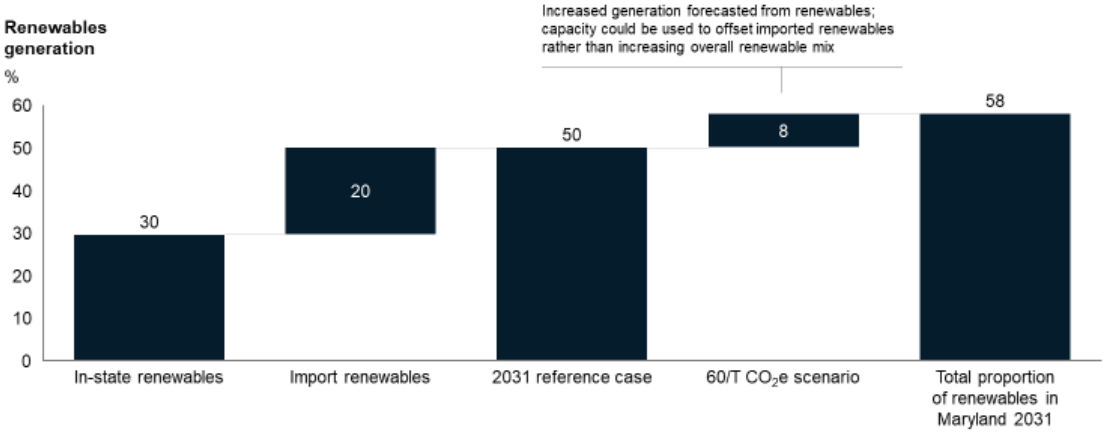
Source: Maryland DoE GGRA plan 2030

Under scenario 2A, the emission reductions achieved in the electricity sector relative to the reference scenario equal 0.45 million tons CO_2e in 2031.

It is estimated that replacing this energy capacity with renewables would be equivalent to an additional 8 percentage-point share in Maryland's total generation capacity under scenario 2A (Exhibit 20).

Exhibit 20

A $60/metric ton CO_2e carbon tax could increase the contribution of renewables by 8 percentage points.



1. Coal and natural gas emission reductions are equivalent to half projected electricity generation from in-state natural gas (combined cycle gas turbine) and coal powered generation. The '60/T CO_2e scenario' represents the additional wind and solar generation required to replace reduced coal and gas generation (shares are equivalent to the 2031 projection).

Source: Maryland DoE GGRA plan 2030

However, under the existing RPS regulations, the increased renewable percentage could be achieved through the purchase of RECs – that is existing generation may not change in Maryland, but an offset of clean energy is purchased from elsewhere in the U.S. Consistent with the approach used to calculate Maryland's GHG inventory, REC purchases, although allowable to meet the RPS goals, are not included in the calculation of GHG emissions.[19] It is also assumed that REC purchases would not discount the carbon price paid by Maryland utilities.

The carbon tax could lead to higher energy prices to customers, as energy providers pass on the increased costs, at least partially, by feeding them through into energy prices. This analysis considers only the price increase from fossil-fuel fired electricity generation, which represents over 50 percent of Maryland's electricity generation (domestically produced and imported).[20] The carbon price does not affect pricing for sources, which do not generate GHG emissions, such as the Calvert Cliffs nuclear generation facility or wind and solar electricity generation. The analysis does not account for a switch toward these sources that the carbon tax would incentivize, which would reduce cost increases for electricity consumers.

Overall, price increases across all fuel types would likely see a similar increase. Under scenario 2A, natural gas and gasoline prices would likely increase in 2023 by 25

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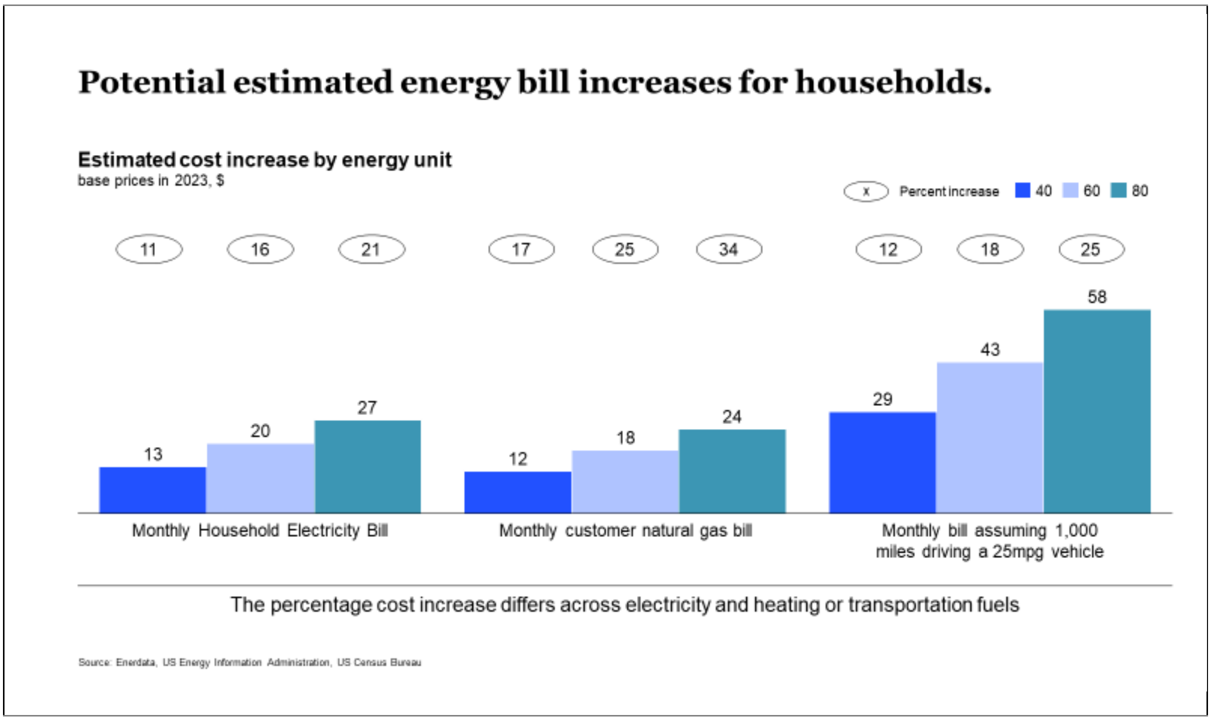
[19] Maryland Department of the Environment (2019), State of Maryland 2017 Greenhouse Gas Emission Inventory Documentation: mde.maryland.gov/programs/Air/ClimateChange/Documents/MD%202017%20Periodic%20GHG%20Emissions%20Inventory%20Documentation.pdf

[20] Based on 2017 PJM grid mix from Maryland GHG Inventory (domestic production and imports).

percent and 18 percent, respectively, compared to a 16 percent increase in the overall electricity price (Exhibit 21).[21]

The $60 per metric ton carbon price under scenario 2A could increase monthly household spending on natural gas and electricity by approximately $40. In 2019, the average Maryland household consumed 975 kWh of electricity and 5,900 cubic feet of natural gas per month.[22] Under scenario 2A, this consumption translates to a $19.93 increase in electricity expenditure and a $19 increase in natural gas expenditure.

Exhibit 21



In the long term, the switch to increasingly cheaper renewable energy may offset increased energy prices. The scenarios in this analysis assume that the cost of renewables will continue to decline over time. However, owing to the conservative nature of the EnerBase MACCs, these scenarios may underestimate the scale and speed of this decline. Historically, renewable electricity deployment has been underestimated. For example, between 1998 and 2015, the International Energy Agency (IEA) predicted annual solar PV capacity growth of 16–30 percent, whereas actual installed capacity grew between 20 percent and 72 percent annually (Creutzig, et al., 2017).

The transition to clean energy will go hand in hand with the decarbonization of end-use sectors, which have significant energy-efficiency benefits. The shift away from

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[21] Based on Maryland energy prices from the EIA: eia.gov/electricity/sales_revenue_price/pdf/table5_a.pdf, eia.gov/dnav/ng/ng_pri_sum_dcu_SMD_a.htm, eia.gov/dnav/pet/pet_pri_gnd_dcus_r1y_a.htm.

[22] EIA: Natural gas estimate based on annual residential sales of 81,845 million cubic feet delivered to 1,164,929 customers and divided by 12 to obtain a monthly average. eia.gov/electricity/sales_revenue_price/pdf/table5_a.pdf, eia.gov/dnav/ng/ng_cons_sum_dcu_SMD_a.htm

fossil-fuel-based technologies may increase energy efficiency. For example, electric vehicles use 73 percent less energy than gasoline vehicles (Energy Transitions Commission, 2020). Research on the U.S. energy system suggests that carbon taxes coupled with strong energy-efficiency policies would produce synergistic effects that could meet deep decarbonization goals (Brown & Li, 2019).

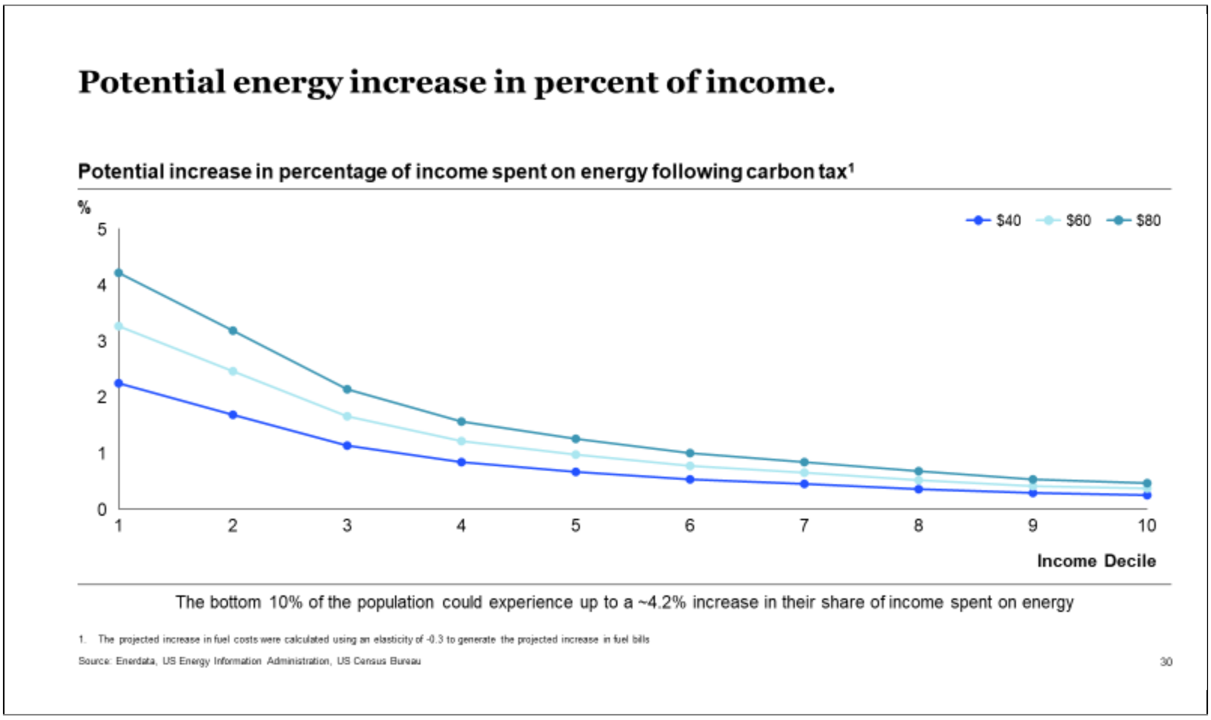
Economic results

Choices around how carbon pricing revenue is used will likely have significant implications on offsetting costs and spurring clean economic growth. Governments could choose to use the revenue generated from their CPIs to compensate households or businesses for the increased costs imposed by carbon pricing, for example. They may also choose a subset of these groups, such as lower-income households. Other options for revenue use include protection against carbon leakage, investing in clean technologies and innovation, and addressing other societal challenges such as education and healthcare. When designed and explained well, revenue use could help increase the political acceptance of a carbon pricing policy.

Impact on households

The increase in energy prices likely affects households differently across income groups. The absolute cost burden of the carbon pricing policy increases with income, as higher-income earners generally have higher overall energy consumption. However, lower-income earners spend a larger proportion of their available income on energy, and therefore, relative impacts are higher. The bottom 10 percent of Maryland's income earners could experience up to a 3.2 percent increase in their share of income spent on energy at a $60 per metric ton pricing level (scenario 2A, see Exhibit 22). Consequently, revenue-recycling options may want to carefully explore how to compensate for the potential impacts of carbon pricing on the most vulnerable.

Exhibit 22



Potential energy increase in percent of income.

Potential increase in percentage of income spent on energy following carbon tax[1]

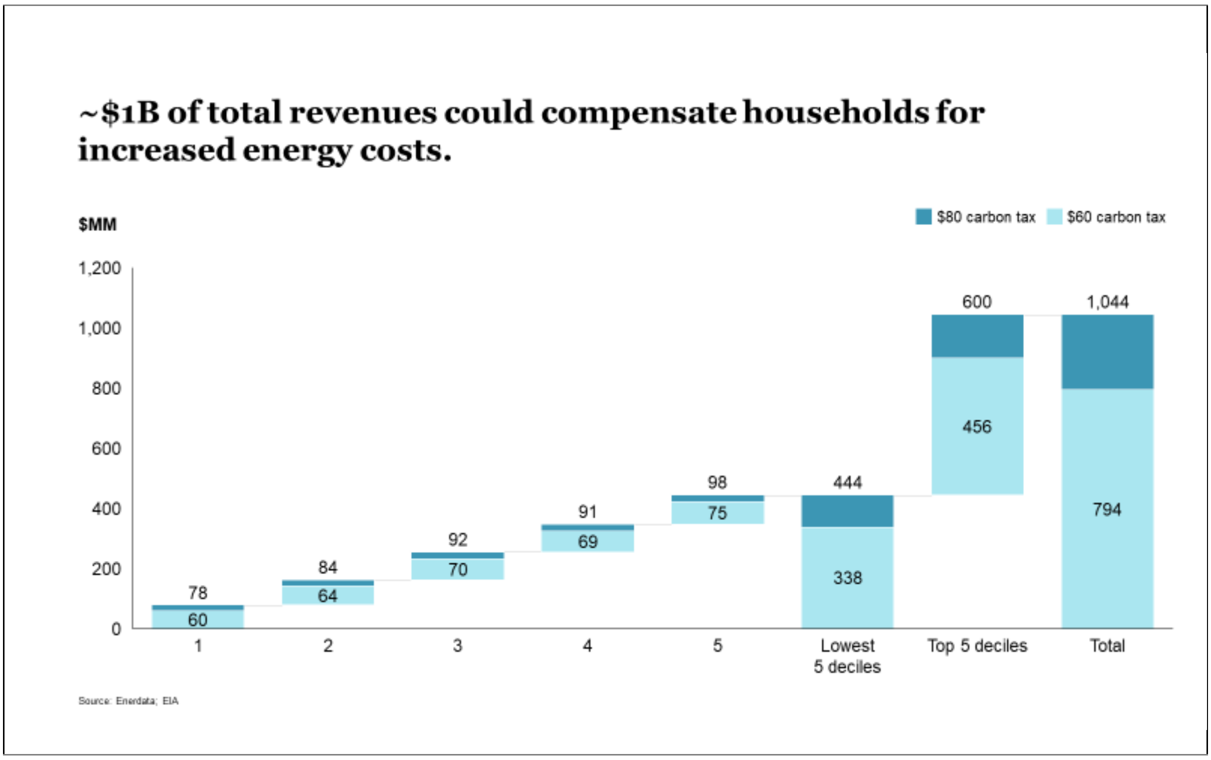
The bottom 10% of the population could experience up to a ~4.2% increase in their share of income spent on energy

[1] The projected increase in fuel costs were calculated using an elasticity of -0.3 to generate the projected increase in fuel bills

Source: Enerdata, US Energy Information Administration, US Census Bureau

Compensating households for their increased energy costs would likely take a modest share of total revenues. Of the $4.1 billion in carbon pricing revenue raised in 2023 under scenario 2A, less than a fifth (19 percent) would be required to compensate all households for the rise in their energy costs (Exhibit 23). Alternatively, only $338 million (8 percent) would be required to offset the increase in energy costs for the lowest-income 50 percent of the population, and only 5 percent would be needed for the lowest 30 percent. This compensation could take the form of direct lump-sum transfers to households or deductions from their income-tax liabilities (with rebates for households with incomes below the income-tax threshold).

Exhibit 23



~$1B of total revenues could compensate households for increased energy costs.

Source: Enerdata; EIA

Impact on industries and commodity prices

Maryland's industries and other businesses would likely also be affected by the carbon pricing policy. This could include large industries that may pay directly for the emissions arising from their operations, as well as broader impacts arising through increases in energy prices. Industries that have a higher emission base in their supply chains experience larger price increases than less emission-intensive industries.

Businesses with the ability to do so will likely pass on much of these increased costs to final consumers.[23] Our rapid assessment analysis finds that prices could increase by 0.4 percent under scenario 1, 0.6 percent under scenario 2A, and 0.8 percent under scenario 3 (Exhibit 24). This assumes a cost pass-through rate of 70 percent in the manufacturing sector.[24]

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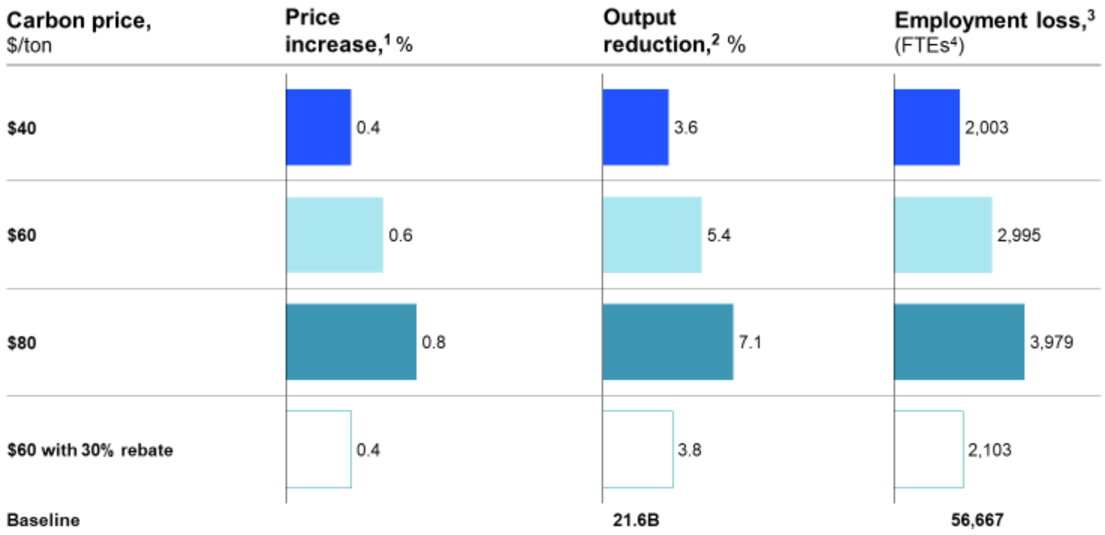
[23] See the next section on carbon leakage and competitiveness as well as the methodology discussion on cost pass-through rates.

[24] The 70 percent pass-through is taken from a UC-Berkeley study that includes a similar mix of industries—Sharat Ganapati, Joseph S Shapiro, & Reed Walker, "Energy cost pass-through in US manufacturing: Estimates and implications for carbon taxes," *American Economic Journal: Applied Economics*, 2020.

Exhibit 24

Economic impacts may vary by carbon-pricing level.



1. Used input, output models to estimate the price increase in goods and assumed that producers can pass on only 70% of costs to consumers
2. Used demand elasticities for each industry to estimate the likely change in demand at the increased price level and reduced output accordingly
3. Employment is assumed to be a fixed proportion of output; as output decreases each industry will experience a decrease in employment
4. Full Time Equivalent

Source: Enerdata, US Bureau of Labor Statistics, US Bureau of Economic Analysis

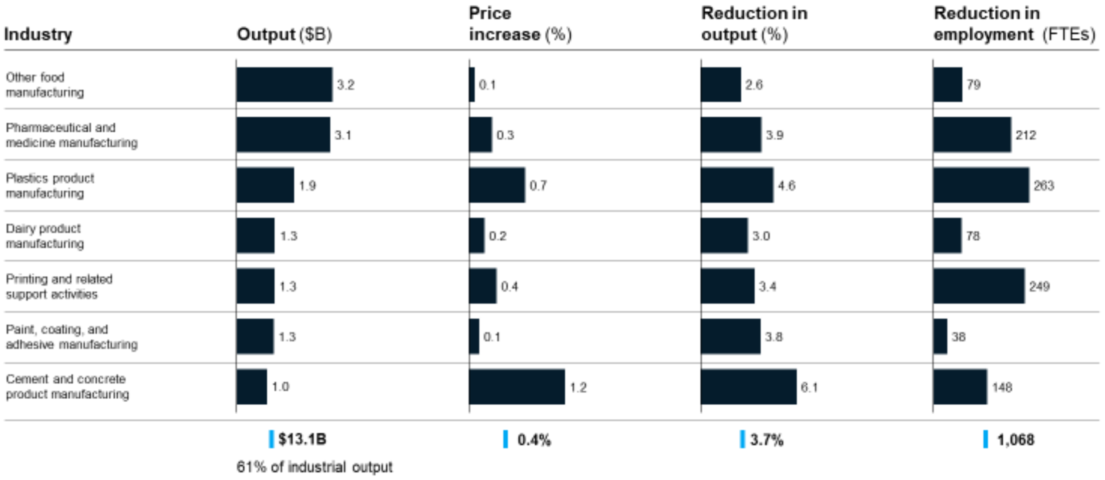
Where firms cannot pass on costs, production and output may fall. The analysis finds that output could fall by as much as 3.6 percent under a $40 per metric ton pricing level, 5.4 percent under a $60 per metric ton pricing level, and 7.1 percent under an $80 per metric ton pricing level. These represent the upper bound to production loss under each scenario because the analysis is static and assumes that firms simply bear the additional costs rather than leveraging abatement responses. For example, firms may invest in energy efficiency or other energy-saving technologies, adopt cleaner technologies, or find innovative ways of reducing emissions. All these options could reduce costs over time.

Government revenue could also potentially be used to offset costs to industries through rebates or subsidies. Concerns regarding increased costs to industries may arise if firms are not able to pass on a sufficient proportion of their costs to final consumers (see next section), or when they need time or support to change production to cleaner alternatives. In these cases, government rebates, tax incentives, or other programs could be considered to help reduce the cost burden of the policy. For example, reinvesting 12 percent of the revenue ($487 million) under scenario 2A to partially compensate industry would decrease the impact of the carbon price on output and price by around 30 percent.

Given that Maryland's economy is predominantly service-based, carbon pricing will likely have a relatively smaller impact on its major sectors and hence on Maryland's GDP than on the national average. Similarly, Maryland's largest five manufacturing industries—with a combined output of $10.9 billion, or half of the total industrial output—would potentially see a lower-than-average price increase and reduction in output compared to the total for all industries (Exhibit 25). Under the $60 per metric ton carbon tax and a 30 percent rebate, the top seven industries could see an average price increase of 0.44 percent and an average output reduction of 3.7 percent.

Exhibit 25

Maryland’s 7 largest manufacturing sectors would be less affected than other industries.[1]



[1] Economic impacts are based on Scenario 2A with 30% revenue recycling

Source: Enerdata, US Bureau of Labor Statistics, US Bureau of Economic Analysis

Impact on employment

In the absence of compensation to affected industries, employment in those traditional industries could fall by between 2,003 and 3,979 full-time positions under the three carbon pricing scenarios (Exhibit 25). Under the highest carbon price scenario, the impact (3,979 jobs at risk) represents approximately 0.2 percent of Maryland’s total employment.[25]

This potential impact could be reduced when revenues are targeted at these industries. Impacts fall to between 1,405 and 2,797 full-time positions if 12 percent of revenues are used to provide rebates to industries as compensation. An alternative or complementary approach to rebates could be retraining programs to help transition workers from emission-intensive to clean-growth industries. For example, according to a 2017 survey conducted by Yale University, 72 percent of Americans would

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[25] Bureau of Labor Statistics, bls.gov.

support using carbon tax revenue to aid workers in the coal industry (Kotchen, Turk, & Leiserowitz, 2017).[26]

In addition, a broader household rebate could create a net-positive impact on employment. If households were each allocated an annual $900 rebate, at a total cost of $2 billion, the additional consumer spending could generate 6,042 jobs within Maryland firms. This gross rebate of $900 translates into a net rebate of $431 (scenario 3), $543 (scenario 2A), or $656 (scenario 1) once the average additional energy costs for the average Maryland household are considered (assuming that those additional costs are not compensated for separately). For the lowest 10 percent of households by income, the net rebate would be $548 (scenario 3), $632 (scenario 2A), or $717 (scenario 1)—assuming that these costs are not separately compensated for. Therefore, targeting revenue toward households could provide a stimulative impact on the Maryland economy that potentially increases total employment within the state.

Importantly, this analysis does not include the impact of employment increases in other sectors that would benefit from a carbon price beyond the use of revenue. This includes less energy-intensive industries, as well as the clean-technology and energy-efficiency sectors. Other studies have found that employment is generally reallocated to new, greener services and other areas and, where revenues are targeted wisely, overall employment can increase (Azevedo, Wolff, & Yamazaki, 2018); Hafstead & Williams, 2018). Likewise, government programs funded through carbon pricing revenue would have additional positive employment effects.

Impact on competitiveness and carbon leakage

Carbon leakage may occur when Maryland's industries are exposed to competition from jurisdictions with less stringent climate policies (e.g., Pennsylvania or West Virginia). Maryland industries that are unable to pass on their carbon-related costs to consumers are likely at risk of competitiveness impacts, where some may choose to shut down or relocate to jurisdictions with less stringent carbon pricing. This relocation outside the state may be coupled with an increase in production of commodities from other jurisdictions that are substituted for Maryland's own production.

This production reshuffling may result in emissions increasing outside Maryland's borders and canceling out any reductions occurring in Maryland's industries due to the carbon pricing policy. At worst, this carbon leakage could see a potential net increase in emissions if production rises in a jurisdiction that is more emission intensive. Thus, carbon leakage is a serious risk from both an economic and an environmental perspective.

Maryland's industries that are most exposed to carbon leakage risk are those that do not have the ability to pass on costs to consumers. This includes commodities such as energy, where prices are fixed on regional, national, and international markets. For

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[26] Matthew J Kotchen et al., "Public willingness to pay for a US carbon tax."

example, the carbon pricing policy would increase the risk of leakage from Dominion’s liquified natural gas distribution center in Cove Point. Other examples include industries that are highly exposed to trade, making product substitution more likely.

Trade intensity and emission intensity are the standard indicators for assessing an industry’s carbon-leakage risk. A 100 percent trade intensity means that all commodities in that sector are either imported or exported—including to and from neighboring states—whereas a 0 percent trade intensity means there are no imports or exports for that sector. A high emission intensity leads to increased overall costs from the carbon pricing policy within affected industrial sectors, and thus higher risks associated with that sector’s competitiveness.[27] When combined with a weaker ability to pass on these costs (as indicated through trade exposure), this increases the risk of carbon leakage.

Anticipating carbon leakage allows it to be potentially addressed through policy design. Instead of industry-wide compensation, targeted rebates could be allocated in proportion to leakage risk. This will likely reduce both the absolute carbon costs faced by these firms and associated competitiveness impacts. However, it is important that rebates are awarded in a way that shields against leakage while preserving the incentive to reduce emissions and adopt clean technologies. This includes policy design that recycles revenue based on performance in terms of emissions per level of output. For example, Canada’s output-based pricing system requires at-risk industries to pay only for excess emissions above a product-specific benchmark.

Maryland’s most at-risk sectors are those that are heavily trade-exposed and require significant energy inputs for production. These include coal mining, basic chemical manufacturing, and textile product mills (excluding household textiles). Coal mining has the highest energy intensity of any sector, at 22.6 percent (Exhibit 26). Coal mined in Maryland provides about one-fifth of the domestic coal that is consumed by the state's coal-fired power plants. However, with both exports and imports high compared to domestic production, the trade metric approaches 100 percent.

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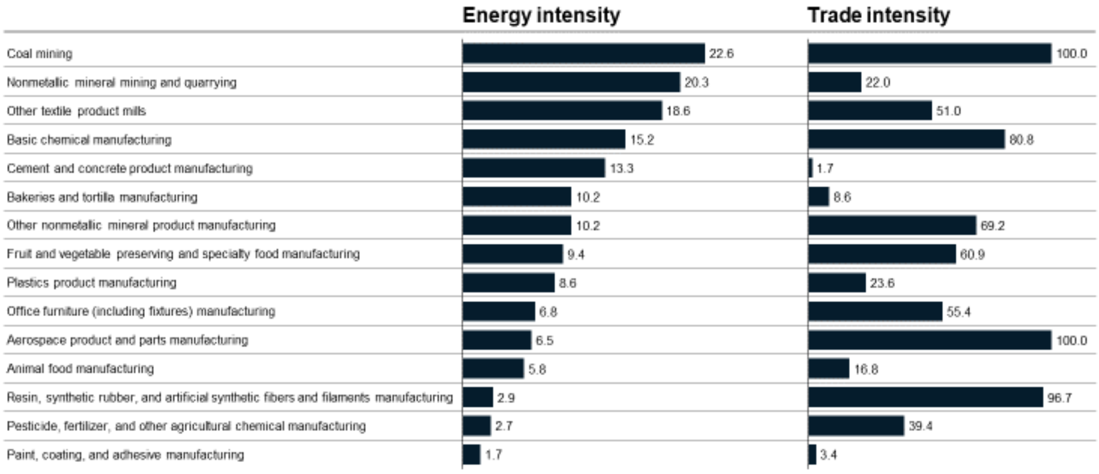
[27] Energy intensity has been used as a proxy for emission intensity in this rapid assessment. Though generally appropriate, this proxy will not fully capture risk characteristics from sectors where industrial-process GHGgreenhouse gas emissions are high, such as chemical manufacturing.

Exhibit 26

Energy intensity and trade intensity vary by manufacturing sector.



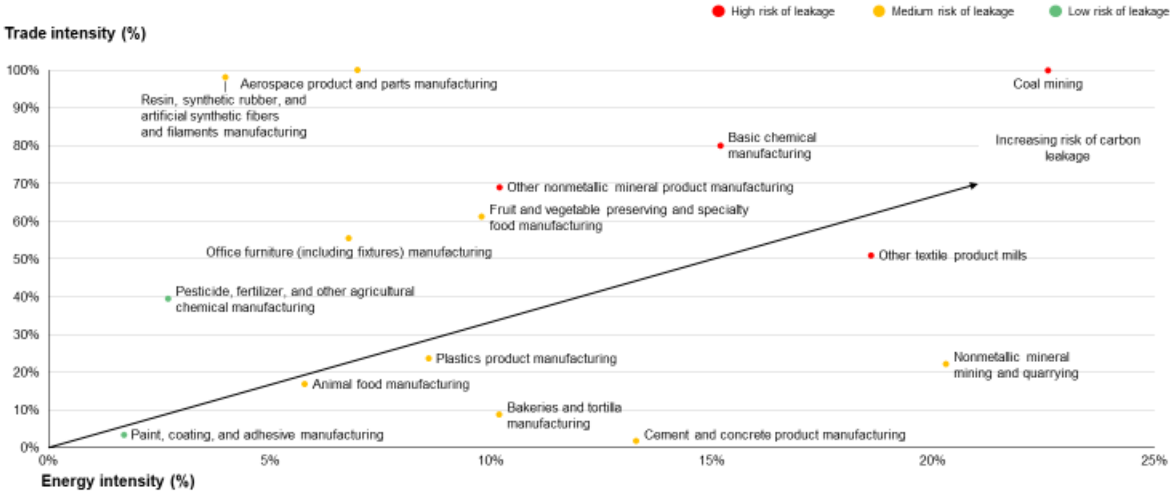
Energy intensity used as a proxy for emissions intensity. Energy intensity does not scale from 0 to 100%. At 20.3%, nonmetallic mineral mining and quarrying (NAICS 2123) is the most energy-intensive industry in Maryland. US energy intensity for the same sector is 7.8 percentage points higher at 28.1%.

Source: Enerdata, US Bureau of Labor Statistics, US Bureau of Economic Analysis

Some sectors, such as nonmetallic mineral mining and quarrying, have a very high energy intensity, but a lower trade intensity putting them at a lower, but still recognizable, risk of carbon leakage. Other sectors, such as aerospace parts manufacturing, are the opposite; they have a high trade intensity but a low energy intensity. Where trade is so high, competitiveness is likely to be an issue even at lower overall cost implications. By plotting trade intensity against energy intensity, industries can be categorized as low, medium, or high risk (Exhibit 27).

Exhibit 27

Energy and trade intensity determine an industry's risk of carbon leakage.



There are several ways to define sectors at most risk of carbon leakage. Here sectors at risk of carbon leakage are those with energy intensity greater than 5% and trade intensity above 15%, or a very high emissions or trade intensity (original proposal from the American Clean Energy and Security Act of 2009).

Source: Enerdata, US Bureau of Labor Statistics, US Bureau of Economic Analysis

SECTION 4: CONCLUSIONS

As Maryland policymakers consider the approach for meeting the state's climate goals, carbon pricing could be an option for further consideration. This initial analysis provides insights into key indicators. However, the complexity of a carbon price, which has an impact on all aspects of an economy, could merit a deeper analysis with economic modeling. Those options could include the following:

- Computable General Equilibrium modeling, which measures the interacting economic impacts from key design choices, such as the use of revenue
- energy-systems modeling, which provides deeper insight into specific changes to energy generation, energy demand, and fuel mix
- co-benefits modeling, which can quantify other benefits, such as air pollution or reduced water use

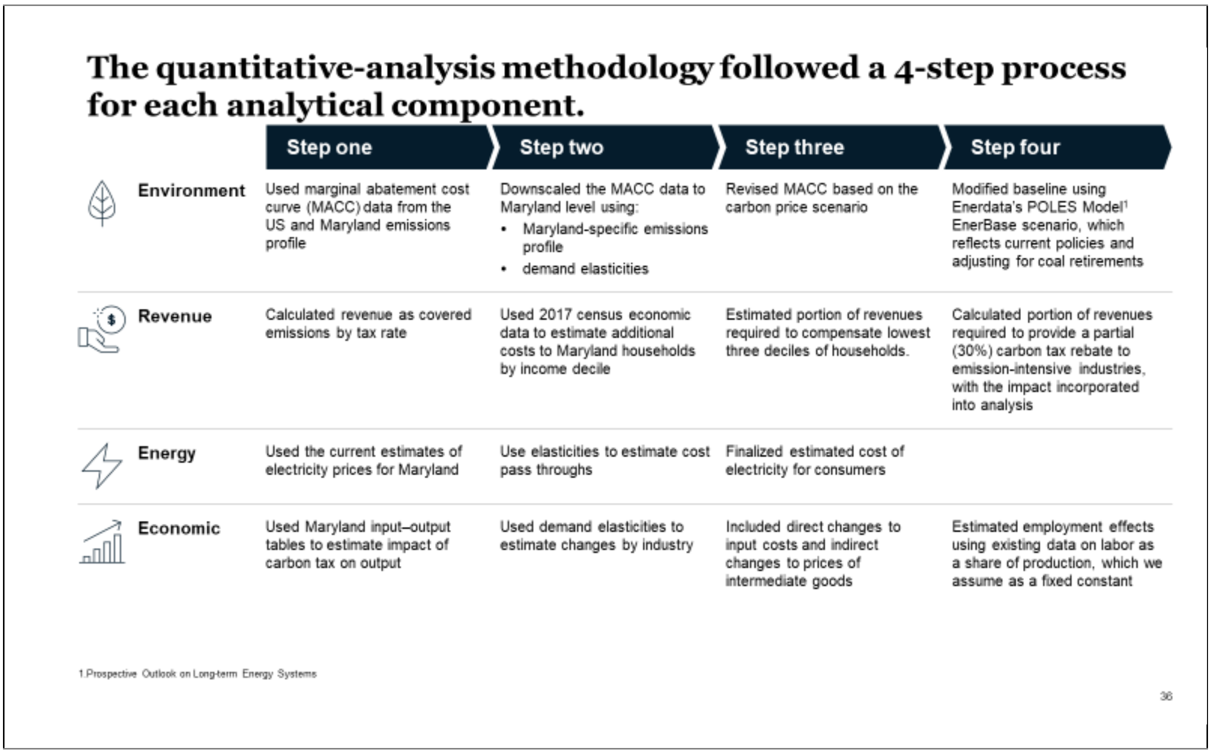
This comprehensive approach may provide further insights into how a carbon price could interact with the Maryland economy and quantify additional benefits such as reduced local air pollution.

APPENDIX: METHODOLOGY

Methodology

The methodology comprised a four-step process followed to produce results for each of the four analytical components: environment, revenue, energy, and economy. The approach used is summarized in Exhibit A. The initial quantitative results for these components allow Maryland to compare across the scenarios described in Section 3.

Exhibit A



The quantitative-analysis methodology followed a 4-step process for each analytical component.

	Step one	Step two	Step three	Step four
Environment	Used marginal abatement cost curve (MACC) data from the US and Maryland emissions profile	Downscaled the MACC data to Maryland level using: • Maryland-specific emissions profile • demand elasticities	Revised MACC based on the carbon price scenario	Modified baseline using Enerdata's POLES Model[1] EnerBase scenario, which reflects current policies and adjusting for coal retirements
Revenue	Calculated revenue as covered emissions by tax rate	Used 2017 census economic data to estimate additional costs to Maryland households by income decile	Estimated portion of revenues required to compensate lowest three deciles of households.	Calculated portion of revenues required to provide a partial (30%) carbon tax rebate to emission-intensive industries, with the impact incorporated into analysis
Energy	Used the current estimates of electricity prices for Maryland	Use elasticities to estimate cost pass throughs	Finalized estimated cost of electricity for consumers	
Economic	Used Maryland input–output tables to estimate impact of carbon tax on output	Used demand elasticities to estimate changes by industry	Included direct changes to input costs and indirect changes to prices of intermediate goods	Estimated employment effects using existing data on labor as a share of production, which we assume as a fixed constant

1.Prospective Outlook on Long-term Energy Systems

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The baseline was aligned to the economic model used to inform the draft 2030 GGRA plan released in February 2021. The quantitative analysis is based on MACCs developed using Enerdata's POLES models. Specifically, the EnerBase scenario is the best representation of a continuation of current policies in Maryland; the baselines in the EnerGreen, EnerBlue, and 2030 GGRA Plan project stronger downward trends than the state's current path (Exhibit B). However, the economic modeling conducted to inform the 2030 GGRA Draft Plan uses the E3 PATHWAYS model and the LEAP modeling tool, therefore adjustments were made to our reference scenario to closely align with the reference scenario used by GGRA.[28] This served two purposes:

- The GGRA reference scenario assumes the continuation of current policies, including implementation of the RPS and RGGI. Aligning the baseline in this analysis validates that the analysis is measuring a specific change from business as usual—in other words, the effect of the carbon price.

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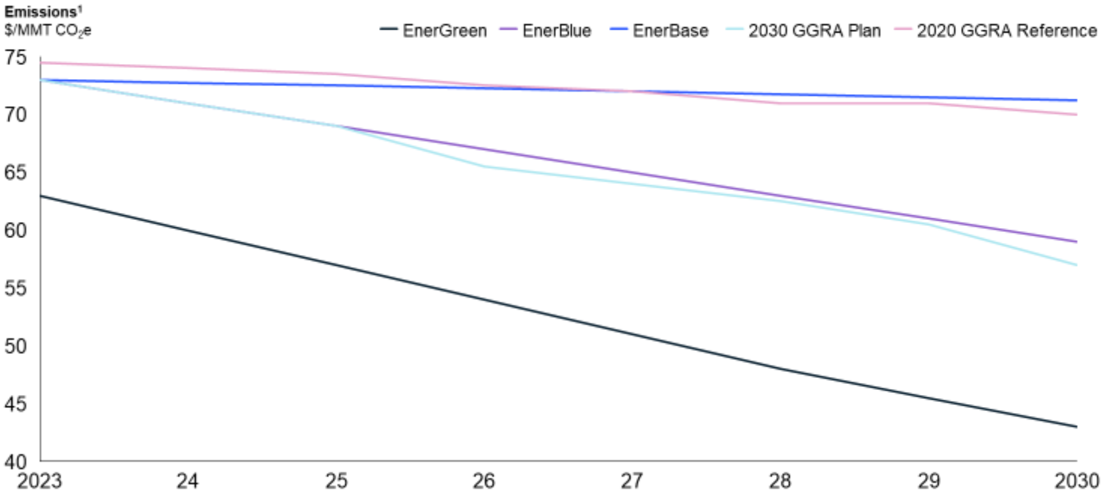
[28] 2030 GGRA Plan, Appendix F, Maryland Department of the Environment, mde.maryland.gov.

- By using similar baselines, it is possible to compare the impact of the carbon tax to that of proposed measures included in the Policy Scenarios modeled in the 2030 GGRA Draft Plan.

Exhibit B

Enerdata's EnerBase scenario was the best match to the GGRA reference scenario.



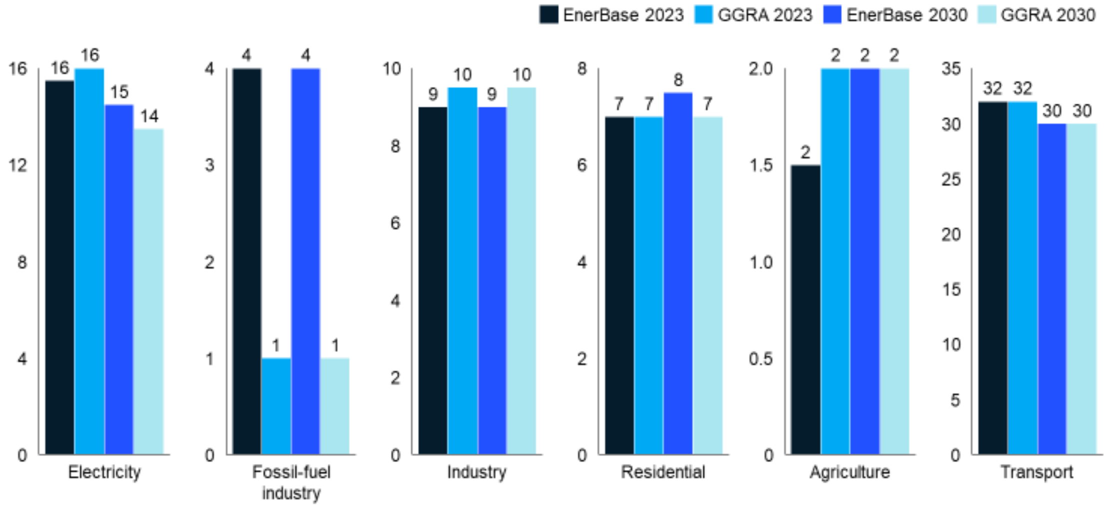
1. Excludes land use which acts as a carbon sink assumed to remain constant at 11.79 MMT CO_2e

Source: Enerdata; Maryland DoE GGRA plan 2030

The baselines also align closely at the sectoral level, but with important distinctions. Our analysis incorporates the GHG emissions from the Cove Point Liquefied Natural Gas terminal, which is not accounted for in the GGRA model. The terminal only commenced operations in 2019 and is therefore not included in the latest GHG inventory released in 2017. Furthermore, because the POLES model uses different categories for its MACCs than those used in the GGRA modeling, some emissions from the GHG inventory are allocated to separate categories (Exhibit C).

Exhibit C

Baselines of the GGRA reference and EnerBase scenarios align closely for most sectors.



Source: Enerdata; Maryland DoE GGRA plan 2030

Emission-reduction assumptions and methodology:

This quantitative analysis commences in 2022, where the carbon price is zero across all scenarios. It introduces the carbon price starting on January 1, 2023, without a transition or ramp-up phase. From 2023 onwards, the carbon price increases by 5% per year. The analysis covers a ten-year window, showing the impact of a carbon price through the end of 2031.

MACCs for each relevant sector are used to estimate the GHG-emission reductions achieved relative to the reference scenario using the carbon price level for each year. Agriculture was included in the aggregate emission totals but is not affected by the carbon tax (it follows the reference-scenario trajectory). Land sequestration is excluded from the analysis altogether.

The emission levels plotted over time represent the total emitted across the entire year. For example, “2024” represents the annual GHG emission forecast to be measured from January 1 to December 31, 2024.

Revenue assumptions and methodology:

Revenue is calculated from the residual emissions covered under the carbon price. Once the emission reductions are accounted for, the analysis assumes that all remaining sectoral emissions are charged the carbon-tax rate (that is, there is no threshold for inclusion under the carbon tax based on facility size or annual GHG emissions). This calculation is used to generate an estimated revenue collected by the carbon price in each year.

For the use of revenue, the analysis estimates a household rebate to offset additional energy costs incurred by the median household and below (explained in next section) and a uniform 30% tax rebate given to manufacturing and industry (see economic assumptions and methodology). In addition, using green-technology job multipliers estimates the investment required to generate the equivalent manufacturing and industry jobs that decrease in the economic analysis. The multiplier range is 5–23 jobs per $1 million invested in various green technologies. To calculate a 1.5 million metric ton sequestration using wetlands conservation and restoration in the Chesapeake Bay, price estimates based on a study examining nature-based solutions in Canada were used. A study calculating carbon valuation in the Chesapeake is forthcoming and would allow for more precise estimates.

Finally, the job impact of a $2 billion household rebate to all Maryland households (equivalent to approximately $900 per household per year) was calculated. This amount equates approximately to the lower estimate of residual revenue after spending on the options listed above. Using the input–output analysis also used to calculate economic impacts, an estimate of the employment impact of a broader household rebate from carbon pricing revenues. An assumption of a marginal propensity to consume of 0.3—a lower estimate than recent COVID-19 federal stimulus, which had an estimated marginal propensity to consume of 0.46. The analysis estimates what this additional spending would mean for employment across the Maryland economy using revenue and job multipliers by subsector (for example, if households receive an additional $900, they spend a certain amount on specific Maryland-produced goods, which generates additional revenues and employment). The aggregate job creation is estimated as potentially amounting to 6,042 full-time-equivalent jobs. Importantly, the analysis includes only the increased spending by consumers within Maryland, rather than additional household consumption that is spent at firms outside Maryland. It also does not consider the emissions impact of this additional household consumption.

Energy assumptions and methodology

Energy prices are calculated using emissions factors for each fuel category (electricity, natural gas, and gasoline). The carbon price is multiplied by the emissions factor to determine the increase in 2023 energy prices from the carbon tax. These fuel price increases are applied to the economic analysis (see below) to determine the impact on Maryland manufacturing and industry.

The distributional analysis uses U.S. Census Public Use Microdata Sample (PUMS) data on 28,000 Maryland households to create a distribution by decile. Income values were aligned to 2019 US dollars to create distribution using 2019 household income data (latest available). For each income decile, the expenditure on different energy sources was calculated as a percentage of total income. Based on expected price increases for various sources of energy the changes in energy expenditure for each income decile was calculated. A price elasticity of -0.3 is assumed. The results provide the additional expenditure by income decile from the carbon tax. The analysis uses broader U.S. census data to aggregate this data across all Maryland households to calculate the total energy cost increases for households. This data is used to calculate the fiscal cost for Maryland to provide a rebate to 50% of households (median income and below) to compensate for the additional energy costs incurred under the carbon tax.

Economy assumptions and methodology

The economic impacts focused on Maryland's industrial sector. Two factors were assessed – economic output and industrial competitiveness.

The economic output analysis focused on impacts on output, earnings, and employment. To estimate these impacts, the first step was to calculate energy cost changes from the carbon tax. Electricity consumption estimates were used based on Economic Census (EC) estimates, disaggregated by industry. These were multiplied by a Maryland-specific emissions factor to calculate the additional costs incurred from the carbon tax.

Using an estimate from academic literature, a cost pass-through of 0.7 or 70% (Ganapati, Shapiro, & Walker, 2020), with the other 30% absorbed by firms, is assumed. The change in demand is calculated by the change in energy costs times the share of energy in total expenditure times the price elasticity of demand. A price elasticity of −0.3 is assumed across industries. The change in demand is then multiplied by the RIMS II input–output demand multipliers to arrive at percentage changes in output, earnings, and employment. The analysis assumes a fixed share of labor in production and hence a 5% decrease in production translates to a proportionate 5% decline in labor employed.

Finally, to model revenue recycling, a scenario where 30% is rebated back to firms is calculated. In practice, the same steps are followed above except that the energy cost increase is "discounted" by the rebate in proportionate terms.

For the industrial competitive analysis, EC statistics divided by North American Industry Classification System (NAICS) code were used. Specifically, the analysis assesses:

- total value of all shipments/sales
- employees
- costs (energy purchases broken down by source, labor costs)

Energy intensity for each industry is calculated as the expenditure on all energy costs divided by the total value of shipments. Trade data is merged in by NAICS code to calculate trade intensity (value of all exports and imports divided by total value of shipments plus imports)

GHG intensity is measured by pricing the CO_2e emissions for each industry and dividing by the total value of shipments. Total energy-use data by NAICS code are used to calculate total energy use. Emissions factors provided by Energy Information Administration data are used to translate energy use into GHG-emission intensity (emissions/unit of output).

The analysis classifies energy-intensive-trade-exposed (EITE) industries as follows:

- > 5% energy intensity and/or > 5% GHG intensity AND
- > 15% trade intensity

This is consistent with the approach used to determine EITE industries in the American Clean Energy and Security Act of 2009. Examples of such industries for Maryland are highlighted in the analysis.

ABBREVIATIONS

CBA – Carbon-border adjustments

CPI – Carbon-pricing instrument

ETS – Emissions Trading Scheme. Also referred to as a “cap-and-trade” system where emissions have a hard cap for a particular industry and each emitter with a certain contribution is required to have “certificates” that prove their emissions are within the cap. The certificates are typically tradeable on a specially defined market.

GDP – Gross Domestic Product. Monetary value of all finished goods and services made within a border of a country or state within a certain time

GGRA - Greenhouse Gas Reduction Act. A 2016 legislation that sets out Maryland’s emission-reduction targets.

2030 GGRA Draft Plan (2019) – A draft report, released in 2019, detailing the recommended set of policies required to reach the GGRA target.

2030 GGRA Plan (2021) – A final, updated version of the 2019 GGRA Draft Plan with more ambitious policies. The report also proposes more ambitious targets of ultimately making Maryland carbon neutral by 2045. As of writing this target has not been passed by the legislature.

GHG – Greenhouse gas

MEA – Maryland Energy Administration. A public-sector entity that advises the Governor on all energy matters.

REC – Renewable Energy Credit. A REC is issued when one megawatt hour of electricity is generated and supplied to the grid from an eligible renewable energy source. These are used to comply with the RPS.

RGGI – Regional Greenhouse Gas Initiative. A cooperative, market-based effort amongst Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, Vermont, and Virginia to cap and reduce carbon dioxide emissions from the power sector.

RPS – Renewable Portfolio Standards. A state-based target that specifies the percentage of electricity that utilities sell that must come from renewable sources.

MACCs – Marginal Abatement Cost Curves. These curves show both the amount of emissions that can be reduced by particular interventions and the average cost per ton of CO_2e required to do that.

MMT CO_2e – Million metric tons (MMT) of carbon dioxide equivalent (CO_2e). CO_2e is the standard unit of GHG emissions used to express the potency of non-carbon dioxide gases (for example, methane) in terms of carbon dioxide emissions (or equivalent).

MRV – Monitoring, reporting, and verification

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