Maryland Department of the Environment

Appendix G

Economic Impacts

2030 GGRA Plan

Appendix G: Economic Impacts

Commissioned by
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Acronyms and Abbreviations

AVERT — Avoided Emissions and Generation Tool
CARES — Clean and Renewable Energy Standard
CHP — Combined heat and power
CTAM — Carbon Tax Assessment Model
COBRA — CO-Benefits Risk Assessment
E3 — Energy and Environmental Economics, Inc.
EPA — U.S. Environmental Protection Agency
GGRA — Greenhouse Gas Emissions Reduction Act
GSP — Gross state product
HCUP — Healthcare Cost and Utilization Project
MCCC — Maryland Commission on Climate Change
MDE — Maryland Department of the Environment
MDOT — Maryland Department of Transportation
MMBTUs — Millions of British Thermal Units
MOU — Memorandum of understanding
MPG — Miles per gallon
MPO Metropolitan Planning Organization
MWG — Mitigation Working Group
NAICS North American Industrial Classification System
NH_3 — Ammonia
NO_X — Nitrogen oxides
$PM_{2.5}$ — Fine particulate matter with a diameter less than 2.5 micrometers
Project Team — RESI and E3
RCCI — Regional Cost Collection Initiative Bill
RESI — Regional Economic Studies Institute
RGGI — Regional Greenhouse Gas Initiative
RPS — Renewable portfolios standard
SO_2 — Sulfur Dioxide
SOC — Standard Occupational Classification
VMT — Vehicle miles traveled
VOCs — Volatile organic compounds

1.1 Executive Summary

The Maryland Department of the Environment (MDE) tasked the Regional Economic Studies Institute (RESI) of Towson University to provide a coherent set of analyses that would inform the development of MDE's proposed plan to reduce statewide greenhouse gas emissions by 40 percent from 2006 levels by 2030. MDE's proposed plan was created to satisfy its obligations under the Greenhouse Gas Emission Reduction Act (GGRA) Reauthorization. To form the Project Team, RESI contracted with Energy and Environmental Economics, LLC (E3) to model changes in emissions arising from various policy bundles under consideration. The results of the emissions modeling, conducted using the PATHWAYS model, are discussed in Chapter 6 of this report. This emissions modeling, along with estimates of program costs from state agencies, formed the base of the economic modeling, which is contained in this chapter. RESI completed the economic modeling using the REMI Model.[1]

The REMI model is a high-end dynamic modeling tool used by various federal and state government agencies in economic policy analysis. The REMI model is calibrated to both the specific demographic features of Maryland as a whole and five distinct regions of the state:

- **Central Maryland**: Baltimore City and Harford, Baltimore, Carroll, Anne Arundel, and Howard Counties;
- **Southern Maryland**: St. Mary's, Charles, and Calvert Counties;
- **Capital Maryland**: Frederick, Montgomery, and Prince George's Counties;
- **Western Maryland**: Garrett, Allegany, and Washington Counties; and
- **Eastern Shore**: Cecil, Kent, Queen Anne's, Talbot, Caroline, Dorchester, Wicomico, Somerset, and Worcester Counties.

Additionally, the Project Team conducted public health modeling to estimate the economic impact associated with improved air quality under each policy scenario.

1.1.1 Criteria for Evaluating the Economic Impact of Policy Scenarios

In addition to satisfying emission requirements through 2030, the policies selected by the State of Maryland to reduce carbon emissions must provide a net benefit to the Maryland economy. To determine whether each policy scenario meets this economic mandate and qualifies as meeting the economic goals of the GGRA, RESI used the following set of indicators:

- Average positive job growth through 2030;
- Positive cumulative personal income growth through 2030 with a 3 percent discount rate; and
- Positive cumulative gross state product (GSP) growth through 2030 with a 3 percent discount rate.

In addition to these three metrics, the Project Team considered other measures of economic well-being, including:

[1] All analyses were conducted using REMI Version 2.2.

- The impact across different sectors of Maryland's economy, including manufacturing;
- The impact on consumer prices;
- Distributional impacts in terms of income, education and training, and race/ethnicity; and
- The regional distribution of jobs.

Reducing carbon emissions and ensuring net benefits to Maryland's economy are not mutually exclusive goals. The following sections will outline the various policy bundles that the Project Team considered, as well as the results of the analysis.

1.1.2 Overview of the MWG Scenario, Draft GGRA Plan and the Final GGRA Plan

In evaluating policies to reduce carbon emissions in Maryland and achieve the goals set in the GGRA plan, the Project Team evaluated a total of four preliminary policy scenarios. Based on these draft analyses, the Draft GGRA Plan was constructed, a subsequent scenario put forth by the Mitigation Working Group (MWG) was constructed, and the Final GGRA Plan was developed. This section provides an overview of these three newer scenarios.

1.1.2.1 Draft GGRA Plan

The Draft GGRA Plan, published in 2019, assumes a continuation or extension of current policies. For example, EmPOWER goals that are currently in place are extended past the expiration year of 2023. In addition to these extensions, the Draft GGRA Plan layers on additional decarbonization efforts, including:

- A 100 percent Clean and Renewable Energy Standards (CARES) goal by 2040;
- Transit bus electrification and other transportation programs; and
- Forest management and healthy soils initiatives.

The Draft GGRA Plan was constructed both to achieve the emissions requirements laid forth in the GGRA and to provide a blueprint for future efforts to reduce greenhouse gas emissions.

1.1.2.2 MWG Scenario

The MWG Scenario established by the working group of the Maryland Commission on Climate Change in 2020 represents an aggressive bundle of decarbonization policies dictated by the working group. In contrast to the Draft GGRA Plan, the MWG Scenario pursues more aggressive:

- Electrification and efficiency in buildings;
- Sales of both light duty and heavy duty Zero Emissions Vehicles (ZEVs);
- Transit bus electrification and other transportation programs; and
- Forest management, healthy soils, and related practices.

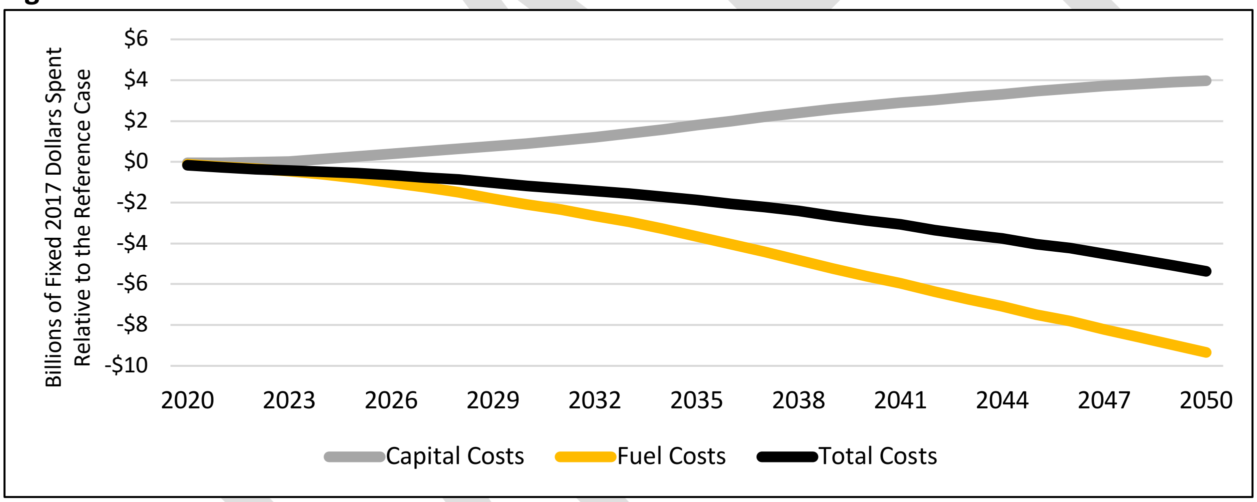
1.1.3 Final GGRA Plan

The Final GGRA Plan represents the plan proposed by MDE to achieve the emissions requirements as specified in the GGRA and provide a blueprint for future efforts to reduce greenhouse gas emissions. The Final GGRA Plan consists of a combination of policies from the MWG Scenario, as well as the Draft GGRA Plan, to determine an economically efficient bundle that yields significant reductions in emissions.

Compared to the MWG Scenario, this plan contains marginally less aggressive policies in a number of sectors, including electrification and increased efficiency in buildings, transportation (including both light and heavy-duty vehicle sales), and industrial energy use. On the other hand, compared to the Draft GGRA Plan, this plan contains significantly more aggressive measures in all the aforementioned sectors.

The Final GGRA Plan achieves the emissions goals with low levels of spending. As illustrated in Figure 1, for every year in the Final GGRA Plan, fuel savings offset capital expenditures, resulting in a net savings for the Maryland economy.

Figure 1: Total Costs from PATHWAYS in the Final GGRA Plan Relative to the Reference Case



Sources: E3, MDE, RESI

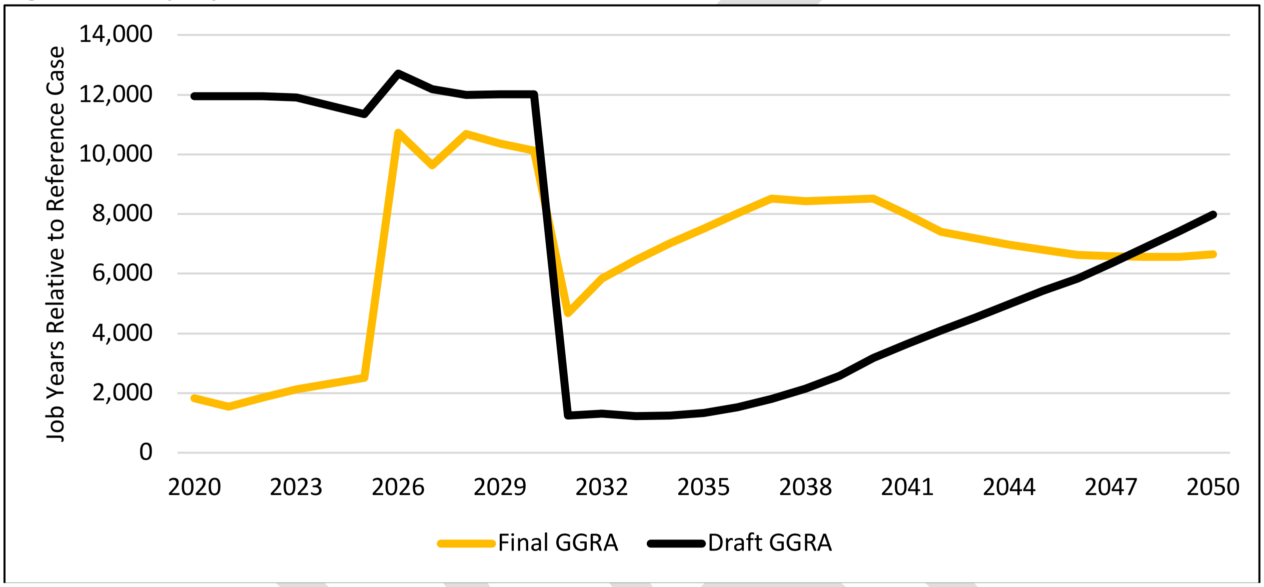
Although consumers and businesses are spending more on capital costs (e.g., new energy-efficient appliances or new electric vehicles) in the Final GGRA Plan than in the reference case, fuel savings exceed this amount every year. This is attributable to two general trends.

1. Spending on transportation infrastructure projects is significant. These projects are generally due to policies aimed at reducing fuel usage through behavioral changes (e.g., increased mass transit usage or increased use of bike lanes), as well as more direct capital outlays (e.g., truck stop electrification or transit bus electrification).
2. Total costs are generally the lowest when compared to the Draft GGRA Plan and the MWG Scenario. In both the Draft GGRA Plan and the MWG Scenario, total costs increase

post-2030 before eventually declining. The Final GGRA Plan has a consistent decline in costs through 2050.

The impacts of infrastructure spending and capital costs can both be seen when examining the economic impacts of the Final GGRA Plan. As seen in Figure 2, the Final GGRA Plan supports an average of 5,788 jobs each year through 2030 relative to the reference case.

Figure 2: Employment in the Final and Draft GGRA Plans Relative to the Reference Case

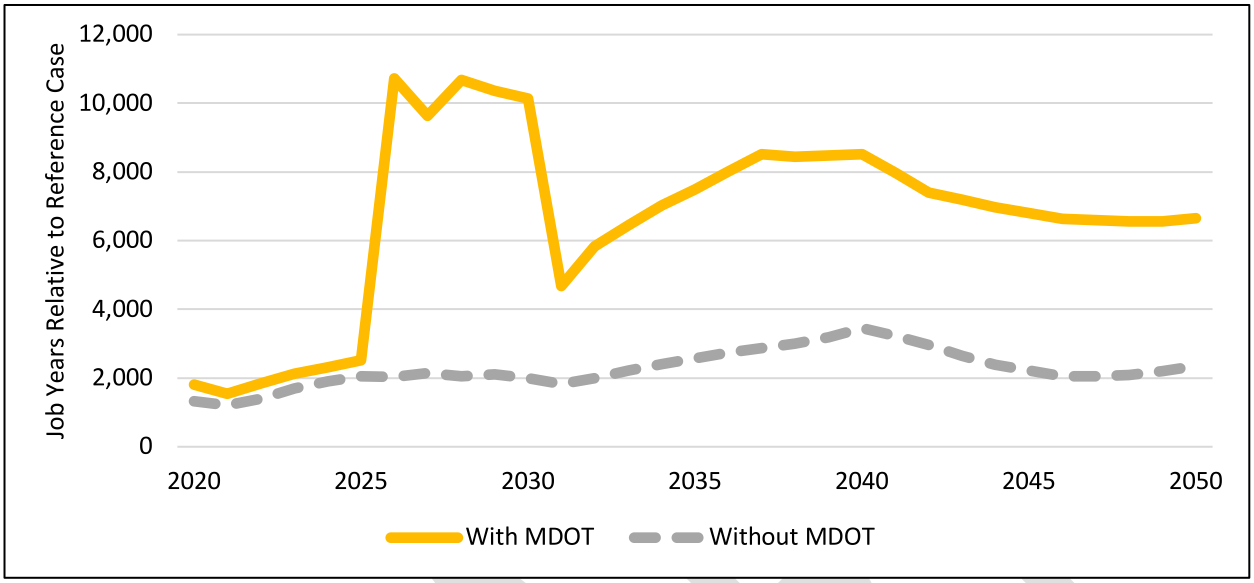


Sources: E3, MDE, REMI, RESI

Through 2030, these employment impacts are driven by transportation infrastructure projects, as seen in other policy scenarios. After 2030, employment impacts remain positive relative to the reference case. As seen above, forecasted employment in the Final GGRA Plan through 2030 is lower than the job gains originally calculated for the Draft GGRA Plan. Since the preparation of the Draft GGRA Plan analysis, MDOT has adopted a new six-year capital budget, called the Consolidated Transportation Program (CTP). This budget includes near-term capital investments that were previously part of the Draft GGRA Plan, but are included in the reference case when calculating the impact of the Final GGRA Plan. This is also true for a number of other policies originally included in the Draft GGRA Plan. The differences in employment between these two plans are primarily due to this change in the reference case, as opposed to an actual change in the total expected number of jobs.

To visualize the impact of transportation infrastructure spending on the economic impact results for the Final GGRA Plan, Figure 3 below shows employment differences for this scenario with and without this spending.

Figure 3: Employment in the Final GGRA Plan With and Without Transportation Spending Relative to the Reference Case



Sources: E3, MDE, REMI, RESI

The impact of transportation spending in the Final GGRA Plan is similar to the impacts in the other three policy scenarios. On average through 2030, transportation infrastructure measures support 3,977 more jobs compared to the scenario without this spending. This is illustrated above as the difference between the two lines. Regardless of the status of the transportation spending, however, employment impacts are steadily positive for the Final GGRA Plan.

After 2030, the positive impacts through 2050 are being driven by two primary factors. First, while capital costs are generally higher than the Draft GGRA Plan, fuel savings are substantially higher in the Final GGRA Plan. This leads to an acceleration in job growth. Second, after 2030 there is significant build-out in the in-state solar industry. This build-out is associated with an increase in jobs in the later years as Maryland invests in locally produced electricity generation.

Figure 4 provides a summary of how each scenario performs in regards to meeting emissions goals (for both 2020 and 2030) as well as the economic goal.

Figure 4: Summary of Policy Scenarios

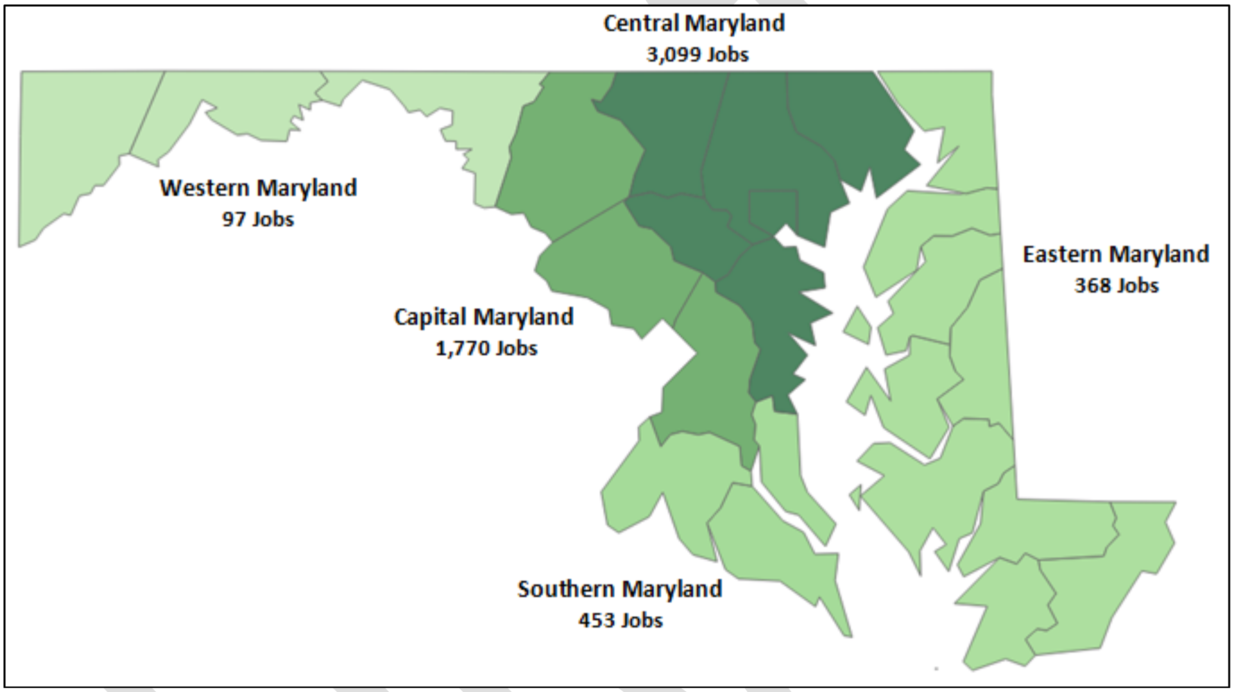
Policy Scenario	Achieve 2020 Emissions Goal?	Achieve 2030 Emissions Goal?	Achieve 2030 Economic Goal?
2019 Draft GGRA Plan	Yes	Yes	Yes
2020 MWG Policy Scenario	Yes	Yes	Yes
2020 Final GGRA Plan	Yes	Yes	Yes

Source: RESI

In sum, all three policy scenarios achieve the 2030 economic goals, as well as the 2020 and 2030 emissions targets. That is, all three policy scenarios exhibit a net positive benefit to the Maryland economy while also reducing emissions by at least 40 percent of 2006 levels by 2030.

In addition, RESI's analysis shows the distributional impacts of the Final GGRA Plan when considered along the lines of geographic region, income level, and race. As shown in Figure 5, all regions of Maryland experience positive job growth relative to the reference case through 2030 for the Final GGRA Plan.

Figure 5: Employment Impacts by Region for Final GGRA Plan

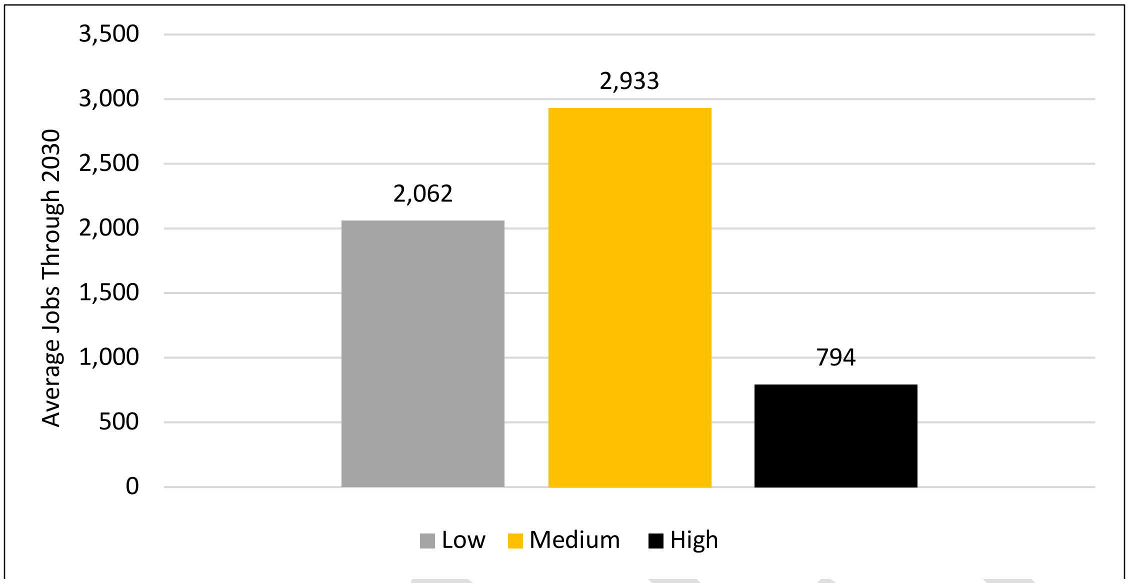


Sources: E3, MDE, REMI, RESI

Under this plan, Central Maryland sustains the largest employment gains of 3,099 jobs. The Capital Maryland region also shows significant employment increases of 1,770 jobs. Central, Eastern, and Southern Maryland have the most significant employment impact when adjusting for population, each gaining a number of annual jobs approximately equal to 0.1 percent of the region's population. Western Maryland adds jobs at only a quarter of that rate.

Employment distribution by wage groups for the Final GGRA Plan are shown in Figure 6 below.

Figure 6: Employment Impacts by Wage Group for Final GGRA Plan

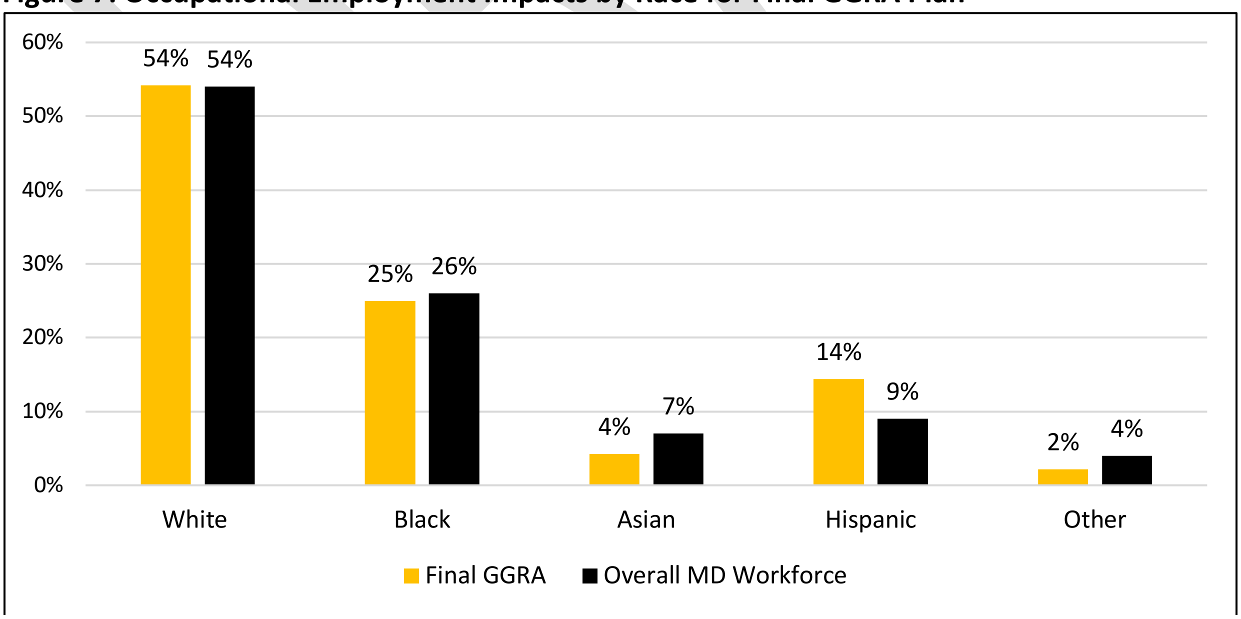


Sources: E3, MDE, REMI, RESI, U.S. BLS

Just over half of the employment impacts under the Final GGRA Plan (2,933 jobs) are found in medium-wage occupations earning between $35,000 and $65,000 annually. A higher number of positions are found in low-wage jobs than high-wage jobs, with more than twice the number of low-wage jobs than in the high-wage category.

Figure 7 shows how employment impacts in the Final GGRA Plan are distributed among racial groups, relative to the state's workforce as a whole.

Figure 7: Occupational Employment Impacts by Race for Final GGRA Plan



Sources: REMI, E3, MDE, MDOT, RESI, U.S. Census

As seen above, employment in the Final GGRA Plan is expected to track closely with the racial breakdown of Maryland's overall workforce, with some differences. Employment for Black and Asian workers is expected to be slightly underrepresented relative to the overall workforce, while Hispanic workers are forecasted to obtain a higher number of jobs relative to their overall representation.

1.2 Introduction

The Maryland Department of the Environment (MDE) tasked the Regional Economic Studies Institute (RESI) of Towson University to provide a coherent set of analyses to inform the development of MDE's proposed plan to reduce statewide greenhouse gas emissions by 40 percent from 2006 levels by 2030. MDE's proposed plan was created to satisfy its obligations under the Greenhouse Gas Emission Reduction Act (GGRA) Reauthorization. To form the Project Team, RESI contracted with Energy and Environmental Economics, LLC (E3) to model changes in emissions arising from various policy bundles under consideration. The results of the emissions modeling, conducted using the PATHWAYS model, are discussed in Chapter 6 of this report. This emissions modeling, along with estimates of program costs from state agencies, for the base of the economic modeling presented in this chapter. RESI conducted the economic modeling using the REMI model. [2]

1.3 Economic Modeling Methodology

As discussed in Chapter 6 of the draft GGRA Plan, the Project Team used the PATHWAYS model to estimate the impact of each policy scenario on greenhouse gas emissions in Maryland. To estimate the economic impacts of each policy scenario, the Project Team used REMI.[3]

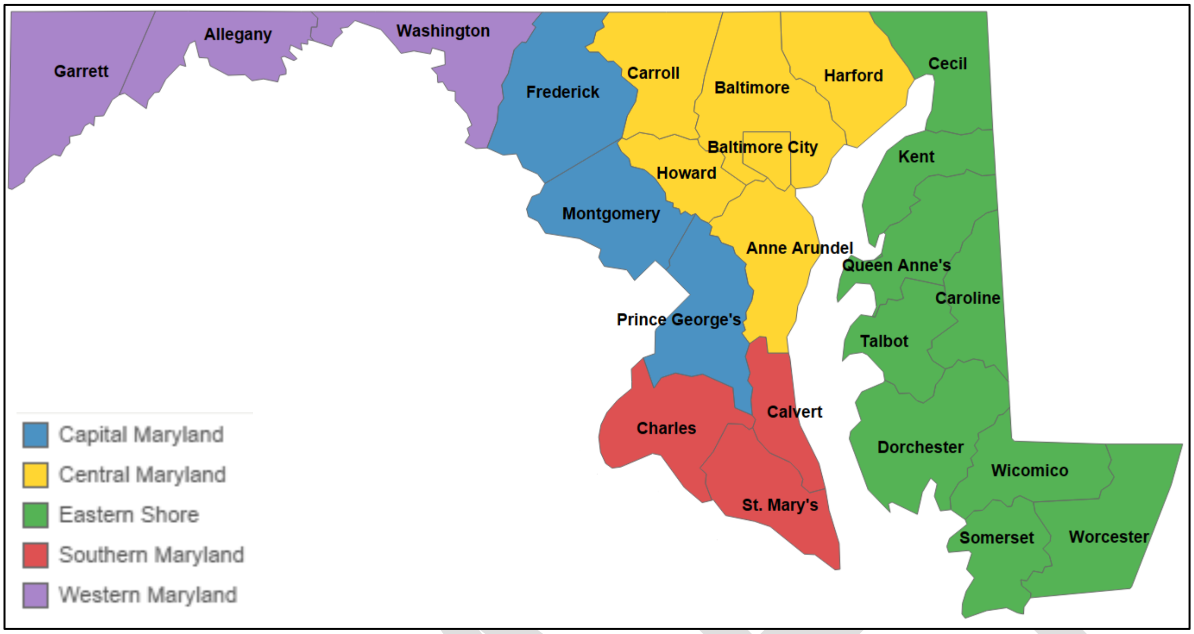
The REMI model is a high-end dynamic modeling tool used by various federal and state government agencies in economic policy analysis. The REMI model is calibrated to both the specific demographic features of Maryland as a whole and five distinct regions of the state:

- **Central Maryland**: Baltimore City and Harford, Baltimore, Carroll, Anne Arundel, and Howard Counties
- **Southern Maryland**: St. Mary's, Charles, and Calvert Counties
- **Capital Maryland**: Frederick, Montgomery, and Prince George's Counties
- **Western Maryland**: Garrett, Allegany, and Washington Counties
- **Eastern Shore**: Cecil, Kent, Queen Anne's, Talbot, Caroline, Dorchester, Wicomico, Somerset, and Worcester Counties

A map of these regions is found in Figure 8.

[2] All analyses were conducted using REMI Version 2.2.

Figure 8: Maryland Counties and Corresponding Region within REMI



Sources: RESI, Tableau

REMI contains a baseline model of the economy for each of the five regions within Maryland. When a scenario is evaluated, REMI calculates the direct impact of the economic event (for example, the sales made to a new business), as well as secondary effects (e.g., the new business' payments to vendors and the money spent in the local economy by workers in the new business). The effects of these effects on the baseline REMI forecast are estimated, allowing researchers to see both the impacts on their own but also in the context of the state's economy. Unlike simpler economic impact analysis models, such as IMPLAN, REMI is a dynamic model. This means that the model also considers economic and demographic shifts between regions (within Maryland and across state lines) in response to the economic scenario.
For example, if a new business opens in Maryland, some workers may move from Virginia or Delaware to be closer to their new employer. The dynamic nature of REMI is important for this analysis, as proposed polices to reduce carbon emissions will lead to changes in consumer prices, salaries, and government spending priorities. Additionally, REMI has a time component, which makes it especially useful in evaluating the long-term impact of policies in the future.

1.3.1 Translating PATHWAYS Output to REMI Input

To ensure that estimates of economic impacts and emissions impacts for each policy scenario were consistent, the Project Team first modeled each policy scenario within PATHWAYS. In addition to calculating changes in emissions for each policy scenario, PATHWAYS also calculates changes in costs for four main sectors of the economy:

1. Residential,
2. Commercial,
3. Industrial, and
4. Transportation.

Across these four sectors, PATHWAYS estimates capital costs associated with 35 distinct subsectors, such as commercial air conditioning, residential clothes washing, transportation light duty automobiles, and residential water heating. Additionally, PATHWAYS produces fuel consumption and fuel cost estimates for a total of 45 different subsectors, such as residential electricity, commercial solar, transportation diesel, and industrial natural gas.

To calculate the economic impact of each policy scenario, the Project Team first translated cost estimates from PATHWAYS into inputs appropriate for REMI. Each cost estimate from PATHWAYS is associated with at least one transfer of funds from one entity to another. For example, if a policy scenario results in increased purchases of residential washing machines, several positive impacts are felt in the economy, including:

- Retail stores experience higher sales, and
- Manufacturers of washing machines experience increased demand and higher sales.

These impacts would generally be associated with job gains, as increased sales may allow stores and manufacturers to hire additional workers. However, in this example, when consumers purchase additional washing machines there are also negative effects on the economy. If consumers spend more of their income on washing machines, they will have less income available to spend on all other goods and services. If consumers forego eating out in order to balance their budget, the economy could experience job losses at restaurants. In other words, it is important to consider not just economic benefits accruing from a given policy, but also the opportunity cost of the new spending.

Therefore, each cost from PATHWAYS produces two inputs for the REMI model: once as a change in spending patterns or production costs from the group bearing the cost of the new policy and once as a change in demand to the industry and group providing the particular good.

Within REMI, there are several ways of modeling the benefits to any given industry. Using the previous example, economic benefits to appliance manufacturers can be modeled through methods such as increased employment in the industry, increased sales, or an increase in consumer/business demand. For this analysis, benefits are generally modeled as a change in consumer/business demand. One advantage of this method is that REMI allows for some portion of the new demand to be satisfied by producers outside of Maryland, which allows for more conservative and accurate estimates than assuming all new production occurs in state.[4]

In addition to modeling benefits, the team also modeled the economic costs associated with each policy, beginning with PATHWAYS output. PATHWAYS categorizes costs as capital costs and fuel costs, both of which correspond to input variables within REMI. An increase in costs increases businesses' production costs, making it more expensive to produce goods in Maryland

[4] When using consumer/business demand, the percent of new demand estimated to be satisfied by in-state sources is estimated to be the same as the percent of local demand satisfied by Maryland producers. For example, if 30 percent of current automobile manufacturing demand is satisfied by in-state sources, 30 percent of all new automobile manufacturing would be satisfied by in-state producers.

as opposed to other states where businesses would not need to invest in the same technologies.

For capital costs and fuel costs impacting households, the Project Team changed REMI's baseline estimates of household spending patterns. For example, if a policy led to consumers spending $30 less on gasoline, the team adjusted household demand for gasoline spending down by $30, and then allowed consumers to spend the $30 on all other goods and services.

1.3.2 Modeling Policy Costs Not Captured Within PATHWAYS

Although the economic impact modeling relied on PATHWAYS output to be consistent with the emissions modeling, not all policies could be explicitly modeled within PATHWAYS. Economic data from PATHWAYS were incomplete because the model was limited to generating cost estimates for items that have a physical stock (e.g., automobiles, appliances, HVAC systems) or that were related to fuels (e.g., electricity, natural gas, diesel). Many policies included investment decisions and benefits not associated with a physical stock.

For example, many policies implemented by the Maryland Department of Transportation (MDOT) would correspond with reduced vehicle miles traveled—and thus emissions—but not a change in the stock of automobiles. Emissions reductions from these policies were still calculated, even though no costs were captured within PATHWAYS. If no cost data were entered separately into REMI, emissions reductions would be achieved for free. Therefore, it was important to capture many changes by state agencies separately instead of relying on PATHWAYS data alone.

One of the largest sources of data to be modeled separately was spending data from MDOT. MDOT data represented a range of different policies across the various policy scenarios, including:

- Public transportation projects,
- Transportation demand management,
- Additional toll roads, and
- More efficient busses.

MDOT policies are modeled within REMI as an increase in the demand for the industry most closely associated with the policy. For example, public transportation projects were generally modeled as an increase in the demand for construction, while updates to the transit bus fleet were modeled as an increase in demand for motor vehicle manufacturing. By increasing the baseline demand values with REMI, REMI assumed some production would be satisfied by out-of-state sources. Note that for the Final GGRA Plan, there was a methodology update regarding MDOT costs post-2030. Instead of assuming no new investment, a linear average of the transportation program line items was used as a proxy for future transportation investments.

Generally, funding for future MDOT projects will come from three broad sources:

- Federal government,

- State government, and
- Private investment.

Funding from the federal government and from private sources was treated as funding that would not be allocated to Maryland otherwise. That is, if the federal government would not provide grant funding to complete a given Maryland project, the team assumed those grant funds would go to another state. Therefore, projects funded by the federal government and private investors represent a positive shock to Maryland's economy.

However, much of the funding needed for transportation projects would originate with the State budget. For these projects, MDOT did not specify the funding source(s) to support the new initiatives. To avoid making broad judgements about which state services would need to be reduced or eliminated to pay for an increase in transportation budgets, the Project Team estimated that state income taxes would change each year by the amount necessary to cover the cost of each project. In instances where spending decreases, particularly due to fuel savings, the team modeled a decrease in state income taxes equal to the savings.[5]

1.3.3 Updating the REMI Baseline

REMI evaluates policy changes in the context of current and forecasted economic conditions, referred to as the standard regional control. Changes to the REMI standard regional control will impact how policies are evaluated in the model. Similarly, policy scenarios within PATHWAYS are evaluated relative to a reference emissions scenario, as described in more detail in Chapter 6. For consistency across models, the REMI standard regional control was adjusted to better align with the reference case in the PATHWAYS model.

The reference case within PATHWAYS assumes the implementation of a variety of policies that are not fully accounted for in REMI's standard regional control. For example, the reference case accounts for Maryland's most recent EmPOWER goals between 2015 and 2023, the most current projections regarding rooftop solar, current renewable portfolio standards (RPS), and changes to the Regional Greenhouse Gas Initiative (RGGI).

Therefore, the Project Team created a new regional control model within REMI that accounts for all policies included in the PATHWAYS reference case. To do so, RESI followed the methodology outlined in Section 1.3.1, increasing capital costs and fuel costs across different sectors of the state economy to more accurately reflect the economy. Once established within REMI, all policy scenarios were run against this new control, rather than the standard regional control.

[5] An alternative approach to the one taken by the Project Team would consist of modeling an increase in demand for the most relevant industry (e.g., construction) and a decrease in general state spending. However, modeling this approach within REMI led to decreases in the employment of teachers and law enforcement personnel. Losses in these occupations are not expected, given the nature of employment contracts for these occupations.

1.3.4 Custom Industries Within REMI

One shortcoming of the REMI model used in this analysis is that all firms producing electric power are aggregated into a single utilities sector. That is, power generated from renewable sources such as wind is modeled identically to power generated from fossil fuels such as coal. This aggregation structure can lead to unintuitive indirect impacts. With the baseline model, an increase in sales of wind energy would be treated the same as an increase in sales of coal power. Because REMI uses one set of economic multipliers to estimate how utility firms spend their revenues on support products and services, an increase in revenue for a wind plant would lead to an increase in purchases of coal or petroleum products within the model.

Therefore, the Project Team separated electric power generation into three categories:

1. Wind electric power generation,
2. Solar electric power generation, and
3. General electric power generation.

General electric power generation uses the same multipliers as the baseline electric power generation sector within REMI. To create the other two custom industries, the Project Team customized REMI using industry multipliers from IMPLAN, another input-output economic modeling software.

To populate the REMI output multipliers, RESI mapped IMPLAN industry classifications to REMI sectors. Because IMPLAN uses a more granular set of industry codes than REMI, some IMPLAN industries were combined. The results were then input into REMI as custom industries.

The solar and wind power generation industries look substantially different than the general electric power generation industry, as illustrated in Figure 9. These industries have a higher value-added component at 0.82 and 0.90, for solar and wind respectively, compared to the base utilities industry, which has a value-added component of 0.79. Because much of the value-added component is due to earnings, on average, it can be expected that jobs in the base utilities industry will be lower paying than those in the solar and wind industries. In terms of intermediate demand, the base utilities industry relies heavily on fossil fuel-intensive industries, such as oil and gas extraction, petroleum and coal products manufacturing, and mining (except oil and gas). Solar and wind, on the other hand, rely more heavily on services (both professional and support services), construction, and real estate.

Figure 9: Top Five Intermediate Demand Industries for Utilities and the Solar and Wind Custom Industries

	Intermediate Demand Industry	Multiplier
Base Utilities	Oil and gas extraction	0.046
	Petroleum and coal products manufacturing	0.033
	Professional, scientific, and technical services	0.019
	Mining (except oil and gas)	0.013
	Scenic and sightseeing transportation; Support activities for transportation	0.012
Solar Power Generation	Professional, scientific, and technical services	0.035
	Scenic and sightseeing transportation; Support activities for transportation	0.019
	Construction	0.016
	Administrative and support services	0.015
	Real estate	0.010
Wind Power Generation	Professional, scientific, and technical services	0.019
	Scenic and sightseeing transportation; Support activities for transportation	0.010
	Construction	0.009
	Administrative and support services	0.008
	Real estate	0.006

Source: REMI, RESI

1.3.5 Estimating Health Impacts

Health impacts and their subsequent economic effects were also evaluated by the Project Team. A reduction in carbon emissions corresponds with increased air quality, leading to a number of health benefits for Maryland residents. These include reduced hospital visits, fewer days missed of work, improved quality of life, and decreased mortality. To estimate these effects, the Project Team used the U.S. Environmental Protection Agency's (EPA) CO-Benefits Risk Assessment (COBRA) model to measure the impacts of reduced emissions on health. The COBRA model is intended to assist state and local governments that are estimating the costs and benefits of clean energy policies. Originally developed by Abt Associates in 2002, and most recently updated in 2017, COBRA is designed to "estimate the economic value of the health benefits associated with clean energy policies and programs," so these values can be weighed against the economic costs of a proposed policy.[6,7]

[6] U.S. Environment Protection Agency, "User's Manual for the Co-Benefits Risk Assessment Health Impacts Screening and Mapping Tool (COBRA)," 3, accessed August 9, 2018, https://www.epa.gov/sites/production/files/2018-05/documents/cobra_user_manual_may2018_508.pdf.

[7] "CO-Benefits Risk Assessment (COBRA) Health Impacts Screening and Mapping Tool," U.S. Environment Protection Agency, accessed August 9, 2018, https://www.epa.gov/statelocalenergy/co-benefits-risk-assessment-cobra-health-impacts-screening-and-mapping-tool.

COBRA utilizes emission estimates for five different forms of air pollution: fine particulate matter ($PM_{2.5}$), sulfur dioxide (SO_2), nitrogen oxides (NO_X), ammonia (NH_3), and volatile organic compounds (VOCs).[8,9] Baseline emission estimates are included for both 2017 and 2025, allowing users to change emissions in either year.[10] Once the emission estimates for the policy are determined, the user can then input any corresponding emission increases or decreases from the baseline into the model. These changes can be input as either percentage changes from the baseline or as a specific quantity of emissions in tons.

To model health impacts through 2050, emission changes from each policy scenario were run for five different years: 2017, 2025, 2030, 2040, and 2050. Since COBRA only contains pre-made baseline emissions for 2017 and 2025, the baseline was increased to adapt for increased emission reductions in the later years of the model.[11]

Except for emissions from electric utilities, all COBRA inputs were derived from PATHWAYS. Final fuel demand (measured in millions of British Thermal Units, or MMBTU) for every sector was calculated as the difference in emissions between the reference scenario and the policy scenario under consideration. The formula for estimating changes in emissions varied by sector.

For example, outside of electric utilities, gasoline and diesel use (particularly in vehicles) makes up the largest portion of emission changes in the policy scenarios. To determine emissions for gasoline and diesel fuels, the change in MMBTUs provided by PATHWAYS was converted into gallons of fuel using conversion rates provided by the U.S. Energy Information Administration.[12] These gallons of fuel were converted into miles traveled using average mileage of 30 miles per gallon (mpg) for gasoline vehicles and 10 mpg for diesel. Finally, miles were converted into emissions using emissions factors prepared for the Project Team by MDE’s Mobile Sources Control Program.[13]

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[8] U.S. Environment Protection Agency, “User’s Manual for the Co-Benefits Risk Assessment Health Impacts Screening and Mapping Tool (COBRA),” 18.

[9] According to the U.S. Environmental Protection Agency, fine particulate matter, or $PM_{2.5}$, typically has a diameter of 2.5 micrometers or less.

[10] COBRA also contains the ability to import a custom emissions baseline for any other year, however this functionality was not used for this analysis.

[11] The baseline emissions were increased using a multiplier on the 2025 baseline so that proportional emissions between counties in Maryland would be preserved. Test runs using various COBRA baselines revealed that the size of the baseline does not have an effect on health impacts as long as proportional emissions between counties remains constant.

[12] “British Thermal Units (BTU),” U.S. Energy Information Administration, accessed January 20, 2019, https://www.eia.gov/energyexplained/index.php?page=about_btu.

[13] Private correspondence with MDE, September 24, 2018.

Emissions for natural gas sectors were calculated using emissions factors for greenhouse gases published by the EPA.[14] These EPA figures allow for a direct conversion from MMBTUs as modeled by PATHWAYS into tons of emissions for $PM_{2.5}$, NO_x, SO_2, and VOCs. The EPA's emissions factors also allow for differentiation in NO_X emissions between commercial/industrial and residential natural gas furnaces.

Certain policy scenarios model the introduction and subsequent increase in use of biogas as a fuel source in Maryland. Emissions created through using biogas are calculated using emissions factors made available by the California Air Resources Board.[15] These factors are directly used to calculate emissions for $PM_{2.5}$, NO_x, SO_2, and VOCs.

Emission changes due to shifting fuel sources in electric utilities are calculated by first using the EPA's Avoided Emissions and Generation Tool (AVERT) modeling program to estimate the change in emissions for each pollutant.[16] Additionally, AVERT is used to estimate emissions reductions resulting from increased generation of wind and solar energy. These emission shifts are then entered into COBRA.

COBRA output consists of various impacts, including:

- Changes in mortality and infant mortality;
- Changes in instances of non-fatal heart attacks;
- Changes in hospital admissions for asthma, chronic lung disease, and all other respiratory issues; and
- Changes in days of work missed due to sickness or days of work with inhibited productivity.

All outputs from COBRA were translated into inputs appropriate for use in REMI. Health impact figures output by COBRA are represented in the COBRA model through an increase in the survival rate, the cost of hospitalization, an increase in the amenity value, a change in productivity, and increased consumer income.[17]
In the REMI model, changes to adult mortality and infant mortality are represented through a change in the survival rate, which represents the percentage of a given population expected to die in a single year. To determine the change in the survival rate, RESI compared the decreased mortality from the COBRA model to the population size of each Maryland region. An

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[14] U.S. Environment Protection Agency, "Natural Gas Combustion," 6, accessed January 20, 2019, https://www3.epa.gov/ttnchie1/ap42/ch01/final/c01s04.pdf.
[15] Marc Carreras-Sospedra and Robert Williams, "Assessment of the Emissions and Energy Impacts of Biomass and Biogas Use in California," University of California and California Biomass Collaborative (January 14, 2015): 63 accessed January 20, 2019, https://www.arb.ca.gov/research/rsc/1-30-15/item6dfr11-307.pdf.
[16] "Avoided Emissions Factors Generated from AVERT," U.S. Environment Protection Agency, accessed January 20, 2019, https://www.epa.gov/statelocalenergy/avoided-emission-factors-generated-avert.
[17] The amenity value measures non-economic improvements to quality of life in a region, which has an effect on migration patterns.

adjustment to the COBRA output was also required to accurately adjust the survival rate for each year.

While most health impacts in COBRA are limited to occurrences within a single year, impacts on premature mortality are determined using a 20-year lag structure. For any change in premature deaths resulting from a single year of emissions, 30 percent of those deaths are assumed to occur in the first year, 50 percent occurs evenly from years two to five after the emissions year, and the final 20 percent occurs over years six to twenty.[18] Mortality changes for each year in the COBRA model were adjusted so that the REMI input reflected the change in mortality that occurs within a given year, rather than the change in mortality caused by a single year of emissions.

Six of the health impacts measured by COBRA involve admittance or visitation to a hospital. To determine the cost of hospitalization for these issues, RESI relied on health data from HCUPnet, an online system which uses data from the Healthcare Cost and Utilization Project (HCUP). Using HCUPnet, RESI obtained average hospital charges in Maryland for each of the relevant conditions.[19] For each reduced incidence of hospital admittance in the COBRA model, RESI decreased medical revenue in the REMI model by an amount equal to the average hospital charge for that condition, reallocating the revenue to consumers, government, and private insurance in proportion to their contribution to the medical bill based on payer data also provided by HCUPnet.[20]

In many cases, a health incident involving hospital admission will result in an absence from work and decreased productivity. COBRA additionally measures missed work days and restricted activity days not directly resulting from one of the other measured health impacts.[21] RESI utilized HCUPnet data to determine the average length of stay for each of the hospital admissions. The productivity gained from a reduction in missed work days was input into REMI as an equivalent increase in employment. RESI calculated the increase in employment by measuring the total reduction in missed work days against the number of active working days in a calendar year.[22]
The change to the amenity value is based on four additional health impacts in the COBRA model: acute bronchitis, upper respiratory symptoms, lower respiratory symptoms, and asthma exacerbation. [23] Since these impacts do not involve hospital admission or missed work days,

[18] U.S. Environment Protection Agency, "User's Manual for the Co-Benefits Risk Assessment Health Impacts Screening and Mapping Tool (COBRA)," F-6.
[19] "HCUPnet, Healthcare Cost and Utilization Project," Agency for Healthcare Research and Quality, accessed August 15, 2018, https://hcupnet.ahrq.gov/.
[20] Revenue was reallocated in the REMI model to insurance carriers, federal, state, and local government, and consumer spending.
[21] For RESI's model, a single restricted activity day is treated as 0.5 missed work days.
[22] Active working days exclude weekends and non-working holidays.
[23] The amenity value in REMI is a "willingness-to-pay" measure representing quality in life. For example, if a state A has cleaner air and water than state B, state A will have a higher amenity value. This higher amenity value means state A will have higher immigration rates with economic indicators changing through that avenue.

they are reflected in the REMI model using a change in the amenity value for each region. The values entered into the model were taken directly from COBRA's valuation of each of the four health impacts.

1.3.7 Criteria for Evaluating the Economic Impact of Policy Scenarios

In addition to satisfying emission requirements through 2030, the policies selected by the State of Maryland to reduce carbon emissions must provide a net benefit to the Maryland economy. To determine whether each policy scenario meets this mandate and qualifies as meeting the economic goals of the GGRA, the Project Team used the following set of indicators:

- Average positive job growth through 2030;
- Positive cumulative personal income growth through 2030 with a 3 percent discount rate; and
- Positive cumulative gross state product (GSP) growth through 2030 with a 3 percent discount rate.[24]

In addition to these three metrics, the team considered other measures of economic well-being, including:

- The impact across different sectors of Maryland's economy, including manufacturing;
- The impact on consumer prices;
- Distributional impacts in terms of income, education and training, and race/ethnicity; and
- The regional distribution of jobs.

Reducing carbon emissions and ensuring net benefits to Maryland's economy are not mutually exclusive goals. The following sections will outline the various policy bundles that the Project Team considered, as well as the results of the economic impact analysis; emissions results are presented in Chapter 1.6 of this report.

1.4 Draft GGRA Plan Results

There are multiple avenues through which policies to reduce Maryland's carbon emissions may impact the state's economy. For example, the construction and installation of solar panels and windmills on the Eastern Shore or construction of additional public transportation infrastructure in Montgomery County would boost employment. On the other hand, if policies lead to more expensive electricity costs for consumers and businesses, overall employment growth may be hampered.

This section provides an overview of the Draft GGRA Plan. The results of this policy are then examined. For more detail on individual assumptions and policies in all policy scenarios, please see Appendix A.

[24] GSP is the sum of consumption, investment, government expenditures, and net exports from the state.

1.4.1 Draft GGRA Plan Overview

The Draft GGRA Plan assumes a continuation or extension of current policies. For example, EmPOWER goals of reduced energy consumption currently in place are extended past the expiration year of 2023. In addition to these extensions, the Draft GGRA Plan layers on additional decarbonization efforts, including:

- A 100 percent Clean and Renewable Energy Standards (CARES) goal by 2040;
- Transit bus electrification and other transportation programs; and
- Forest management and healthy soils initiatives.

The Draft GGRA Plan was constructed both to achieve the emissions requirements laid forth in the GGRA and provide a blueprint for future efforts to reduce greenhouse gas emissions.

The following sections contain the economic results of the Draft GGRA Plan.

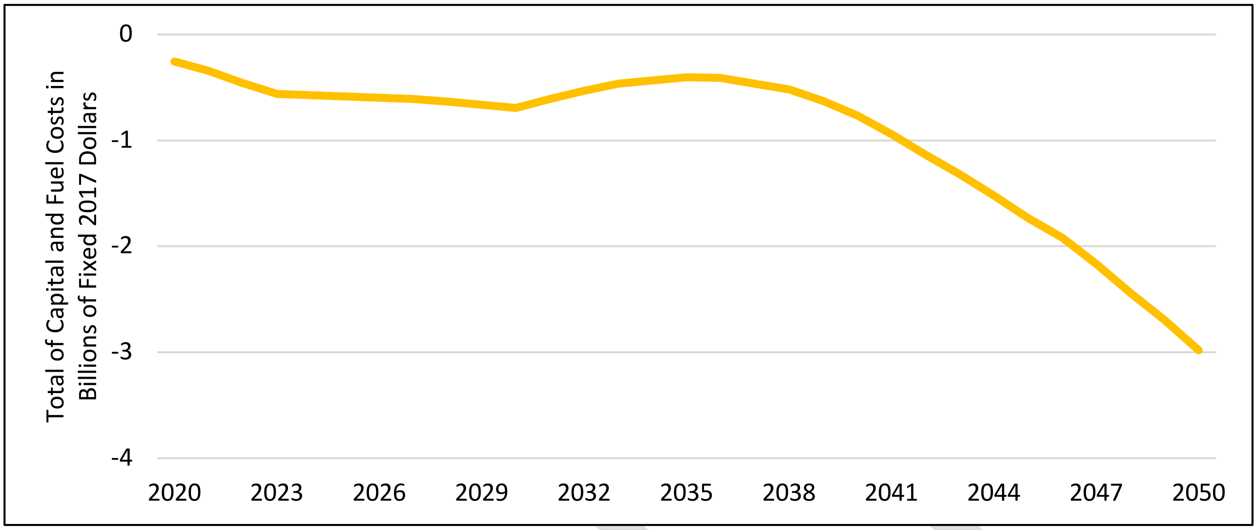
1.4.2 Spending and Electricity Demand in the Draft GGRA Plan

Within this policy scenario, there are two broadly competing forces: capital costs and fuel savings. Generally, the price of fuel increases across policy scenarios, as relatively cheap but carbon-intensive fuels are replaced by more expensive alternatives. To offset rising prices and comply with new regulations, consumers and businesses make investments in new technologies. The hope is that the initial cost of these investments will be outweighed by future fuel savings.

For example, if a consumer purchases an electric vehicle, that purchase may be considered cost effective if fuel savings outweigh the initial purchase premium above a gasoline-powered car. However, if fuel savings are not enough to compensate for the initial capital expenditure, the vehicle is not considered cost effective.

PATHWAYS data can broadly illustrate this effect. Ideally, savings on fuel will outweigh the cost of switching to more energy-efficient technologies, and the total cost for this policy scenario will be lower than in the reference case. As seen below in Figure 10, total costs for the Draft GGRA Plan remain lower than the reference case through 2030, with costs reducing to an even greater degree through 2050.

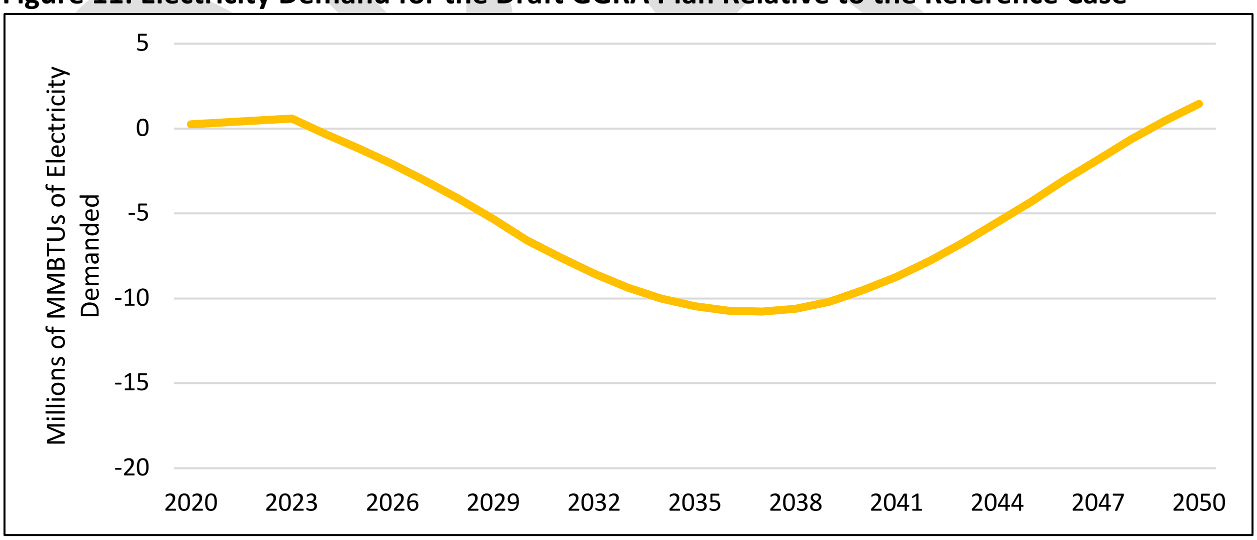
Figure 10: Total Costs for the Draft GGRA Plan Relative to the Reference Case



Sources: E3, MDE, RESI

In the Draft GGRA Plan, electricity demand remains low compared to the reference case, as seen in Figure 11. When viewed in conjunction with Figure 10, as total costs increase, electricity demand tends to decrease. As consumers and businesses invest in energy efficient appliances, this lowers the electricity demanded in the middle years. In the later years, as more of the economy (including the transportation sector) transitions away from fossil fuels and towards renewable electricity generation, demand rises again.

Figure 11: Electricity Demand for the Draft GGRA Plan Relative to the Reference Case



Sources: E3, MDE, RESI

1.4.3 Employment

To meet the economic goals as described in Section 1.3.7, policy scenarios must achieve positive job growth, on average, through 2030. This section presents a description of the measures used to analyze employment results, as well as detailed employment results for the Draft GGRA Plan.

1.4.3.1 Measures of Employment

In addition to the total employment trends, the following aspects will also be addressed for each policy scenario:

- Sensitivity analyses,
- Regional distribution of job impacts,
- Employment impacts by industry,
- Employment impacts by occupation,
- Employment impacts by job zone,
- Employment impacts by income levels, and
- Employment impacts from improved health outcomes.

Sensitivity analyses were conducted by evaluating employment impacts both with and without MDOT transportation measures. This was done due to the magnitude of the job impacts that resulted from this MDOT spending, and to provide a range of expected employment effects if funding levels vary from the initial projections.

Employment impacts were evaluated for the five-region Maryland model described in Section 1.3, which includes:

- **Central Maryland**: Baltimore City and Harford, Baltimore, Carroll, Anne Arundel, and Howard Counties;
- **Southern Maryland**: St. Mary's, Charles, and Calvert Counties;
- **Capital Maryland**: Frederick, Montgomery, and Prince George's Counties;
- **Western Maryland**: Garrett, Allegany, and Washington Counties; and
- **Eastern Shore**: Cecil, Kent, Queen Anne's, Talbot, Caroline, Dorchester, Wicomico, Somerset, and Worcester Counties.

Industries were defined using North American Industrial Classification System (NAICS) codes.[25] NAICS categorizes industries into two- through six-digit codes, with two-digit codes representing the broadest industry definitions, and six-digit codes representing specific industries on a more granular level. For employment results shown within this section, jobs were categorized into two-digit NAICS (industry) codes.

Jobs were categorized into professions using the Standard Occupational Classification (SOC) system. Similar to the structure of NAICS codes, this system organizes jobs from broad major

[25] "North American Industry Classification System," U.S. Census Bureau, accessed February 14, 2019, https://www.census.gov/eos/www/naics/.

groups to more detailed occupations.[26] For employment results shown within this section, occupations were categorized into major SOC groups (codes at the two-digit level).

Job zones were developed by O*NET, which categorizes jobs based on their similarities regarding education, related experience, and on-the-job training requirements.[27] These zones range from one through five, with Job Zone 1 requiring little to no preparation (e.g., dishwashers), and Job Zone 5 requiring many years of preparation (e.g., attorneys). Employment effects within this section are classified as follows.

- Job Zone 1: Some occupations may require a high school diploma or equivalent, and training would be expected to take several days to several months.
- Job Zone 2: Most occupations require a high school diploma or equivalent, and training would be expected to take several months to a year.
- Job Zone 3: Occupations typically require some additional education, such as vocational school or an associate degree, with training expected to take one to two years.
- Job Zone 4: Often require a bachelor's degree, with several years of training expected.
- Job Zone 5: Most occupations require an advanced degree, such as a master's degree or Ph. D., and may require additional training for specialization following degree attainment.[28]

The jobs supported by each policy scenario were further examined based on wage group. Each occupation was categorized into one of three groups based on median earnings for Maryland. These groups were categorized based on the following annual wages:

- Low-wage jobs: less than $35,000;
- Medium-wage jobs: between $35,000 and $65,000; and
- High-wage jobs: more than $65,000.[29]

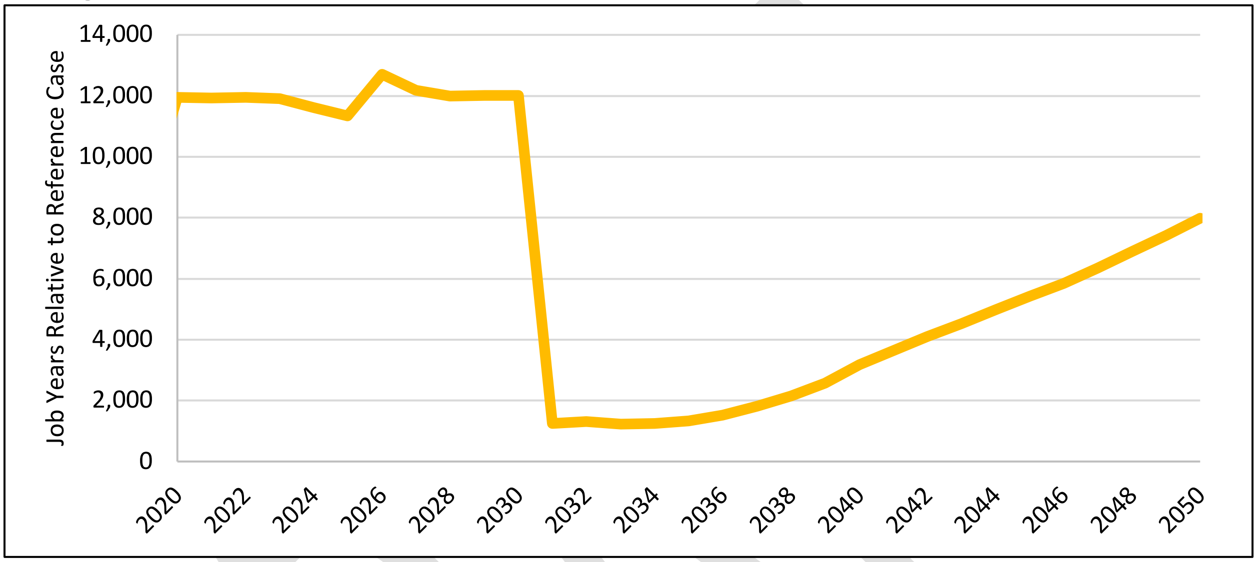
Improved health outcomes affect employment through numerous avenues. First, because mortality is reduced due to cleaner air, the population survival rate increases. This subsequently causes the number of available workers in the labor pool to rise. Second, a reduction in morbidity will increase the labor productivity of workers as fewer sick days are taken. Third, while hospitals will receive less revenue from treating fewer patients, this money will be cycled back to consumers, insurance companies, and federal and state governments. The net employment effects depend upon on the structure of the economy and magnitude of the medical expenditures. Employment effects shown in this section consider each of these components when generating a net impact.

[26] "Standard Occupational Classification," U.S. Bureau of Labor Statistics, accessed February 14, 2019, https://www.bls.gov/soc/home.htm.
[27] "O*NET OnLine Help: Job Zones," O*NET OnLine, accessed February 13, 2019, https://www.onetonline.org/help/online/zones.
[28] "O*NET OnLine Help: Job Zones," O*NET OnLine.
[29] Wage categories were selected which roughly categorize Maryland's workforce into three equal groups. Therefore, if jobs are distributed equally across income levels, we would expect to see an equal number of jobs in all three groups.

1.4.3.2 Employment in the Draft GGRA Plan

The Draft GGRA Plan achieves the economic goal of positive job growth through 2030. Figure 12 shows how employment levels vary over time in response to the Draft GGRA Plan. On average, the Plan supports 11,963 jobs each year through 2030 relative to the reference case.

Figure 12: Employment by Year for Draft GGRA Plan with Transportation Measures 2020 Through 2050

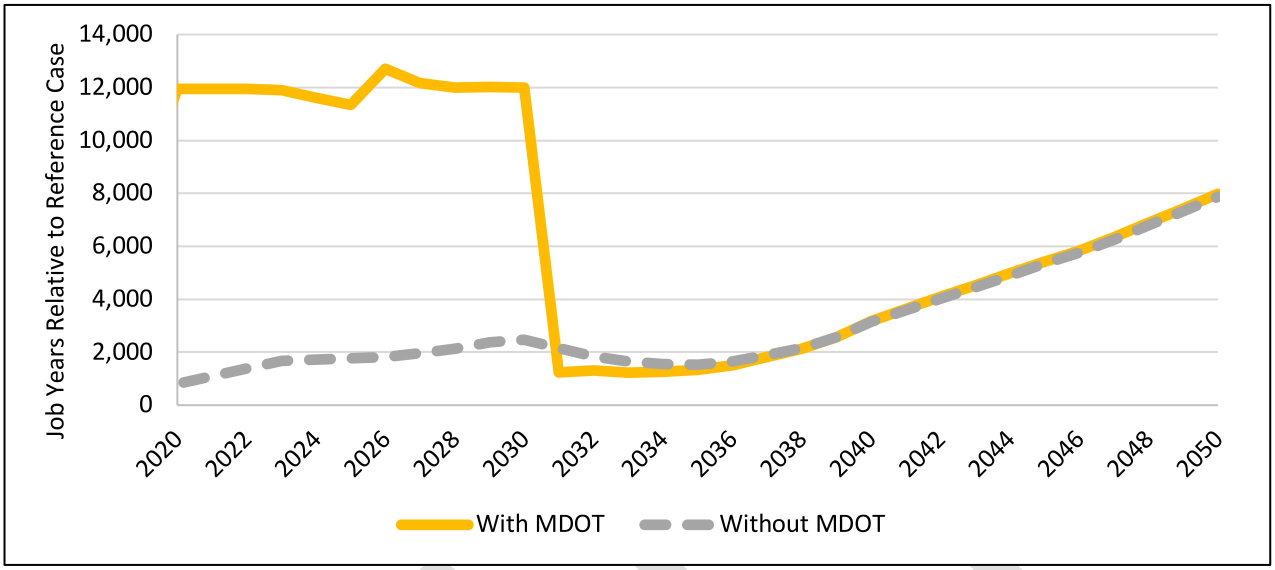


Sources: REMI, E3, MDE, MDOT, RESI

In the short term, employment gains are relatively high, due to spending on a variety of infrastructure projects, including new funding for Metropolitan Planning Organization (MPO) plans and programs. Many of these infrastructure projects are set to be completed by 2030, corresponding with the decrease in job growth seen at this time. After 2030, job growth relative to the reference case slows and approaches zero. Even so, employment under the Draft GGRA Plan is greater than employment in the reference case. During this time, capital expenditures significantly outweigh reductions in energy consumption. One reason for this is the extension of EmPOWER, which begins in 2024 and extends through 2050. Additionally, new sales of zero emission vehicles in the later years of the study period are captured as increased capital costs. The fuel savings from these policies is seen in later years. After 2045, fuel savings outweigh capital costs and lead to higher growth relative to the reference case.

Another driver behind the employment patterns seen in Figure 12 is the increase of in-state renewable energy production. As Maryland’s energy mix shifts from out-of-state fossil fuel and towards in-state wind and solar generation, new jobs are created in Maryland.

Figure 13: Employment with and without Transportation Measures in Draft GGRA Plan



Sources: E3, MDE, MDOT, RESI

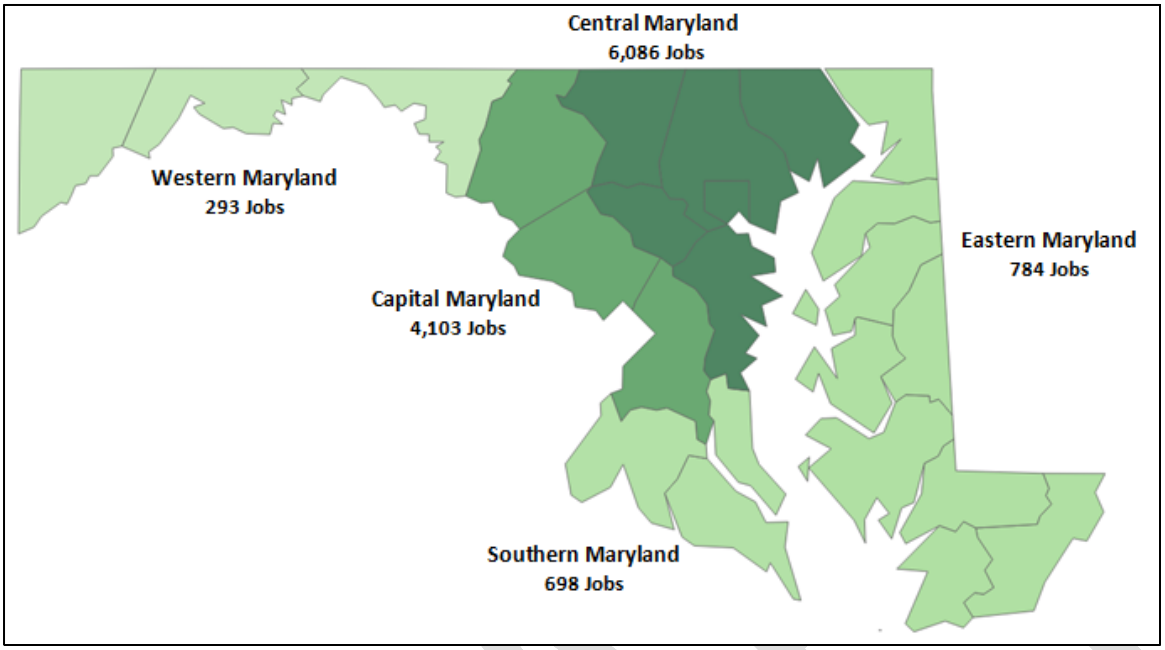
Although transportation spending in the near term constitutes a large percentage of the employment impacts, Figure 13 shows that job growth is dominantly positive relevant to the reference case, even after removing transportation spending from the model. Transportation spending in the Draft GGRA Plan consists of two main phases as seen in the graph below as the difference between the “with MDOT” line and “without MDOT” line.

The majority of spending and associated jobs impacts occurs prior to 2025. A number of smaller projects extend through 2030, representing the smaller, yet significant difference between the employment estimates with and without MDOT measures. On average through 2030, the scenario without MDOT spending supports 10,215 fewer jobs annually compared to the scenario with MDOT spending, though both scenarios increase employment levels over the reference case.

As with each policy scenario evaluated, these employment effects will not be uniformly distributed across the various regions of the state. Each region of Maryland has a unique local economy that will respond differently to the policies outlined in each scenario, based on the composition of industries within the area. For example, Capital Maryland, which is heavily reliant on the on government and services industries, would be impacted differently by policies primarily affecting these industries than the Eastern Shore, where farming and natural resources industries are dominant.

As shown in Figure 14, no region within the state experiences job losses on average through 2030, relative to the reference case. Central Maryland has the largest gains with 6,086 jobs while the smallest gain of 293 jobs occurs in Western Maryland.

Figure 14: Average Annual Employment Impacts by Region for the Draft GGRA Plan, 2020 - 2030



Sources: E3, MDE, RESI

Figure 15 outlines the composition of employment gains by industry.

Figure 15: Average Annual Employment by Industry for the Draft GGRA Plan, 2020 - 2030

NAICS	Industry	Average Annual Jobs Through 2030
11	Agriculture, Forestry, Fishing and Hunting	143
21	Mining, Quarrying, and Oil and Gas Extraction	-29
22	Utilities	185
23	Construction	8,746
31-33	Manufacturing	128
42	Wholesale Trade	82
44-45	Retail Trade	-223
48-49	Transportation and Warehousing	98
51	Information	26
52	Finance and Insurance	104
53	Real Estate and Rental and Leasing	163
54	Professional, Scientific, and Technical Services	317
55	Management of Companies and Enterprises	20
56	Administrative and Support and Waste Management and Remediation Services	219
61	Educational Services	65

62	Health Care and Social Assistance	585
71	Arts, Entertainment, and Recreation	44
72	Accommodation and Food Services	309
81	Other Services (except Public Administration)	275
92	Public Administration	707
Total		**11,964**

Sources: E3, MDE, REMI, RESI, U.S. Census

As detailed above, the vast majority of these jobs—8,746 of the 11,964 total jobs—are estimated to be in the construction industry, which is likely reflective of the transportation infrastructure projects. Conversely, Retail Trade posts the largest decline of -223 jobs, followed by a small loss of 29 jobs in Mining, Quarrying, and Oil and Gas Extraction. A significant proportion of retail job losses are likely attributed to projected declines in gas station use, as consumers shift from gasoline-fuel vehicles to electric and hybrid vehicles. Notably, however, these impacts may be lessened if gas stations shift with market demand to repurpose as charging stations. The REMI model assumes a relatively consistent structure of the Maryland economy over time and would not account for these dynamic or innovative industry changes.

Figure 16 below shows the distribution of employment impacts by occupation. Please note that the total average number of jobs may not match the industry total due to rounding.

Figure 16: Employment by Occupation for Draft GGRA Plan

SOC Code	SOC Description	Average Jobs Through 2030
11	Management Occupations	721
13	Business and Financial Operations Occupations	473
15	Computer and Mathematical Occupations	123
17	Architecture and Engineering Occupations	170
19	Life, Physical, and Social Science Occupations	35
21	Community and Social Service Occupations	68
23	Legal Occupations	37
25	Education, Training, and Library Occupations	306
27	Arts, Design, Entertainment, Sports, and Media Occupations	51
29	Healthcare Practitioners and Technical Occupations	225
31	Healthcare Support Occupations	131
33	Protective Service Occupations	109
35	Food Preparation and Serving Related Occupations	296
37	Building and Grounds Cleaning and Maintenance Occupations	190
39	Personal Care and Service Occupations	231
41	Sales and Related Occupations	210

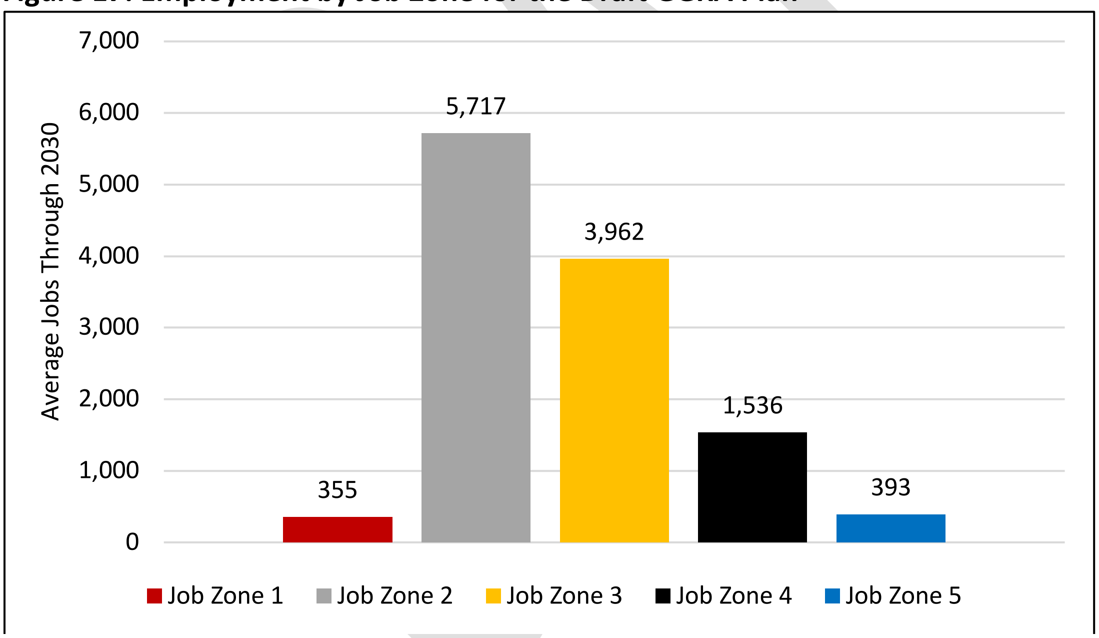
43	Office and Administrative Support Occupations	1,237
45	Farming, Fishing, and Forestry Occupations	82
47	Construction and Extraction Occupations	5,520
49	Installation, Maintenance, and Repair Occupations	964
51	Production Occupations	297
53	Transportation and Material Moving Occupations	488
Total		**11,963**

Sources: E3, MDE, REMI, RESI, U.S. BLS

The greatest employment gains are projected to be in Construction and Extraction Occupations with an estimated 5,520 jobs, and are likely supported by the marked increase in construction activity, in large part, to transportation infrastructure projects. The second-highest increase is shown in Office and Administrative Support Occupations (1,237 jobs), followed by increases in Installation, Maintenance, and Repair Occupations (964) and Management Occupations (721).

Figure 17 below shows the distribution of employment changes by job zone, as previously defined in Section 1.4.3.1.

Figure 17: Employment by Job Zone for the Draft GGRA Plan

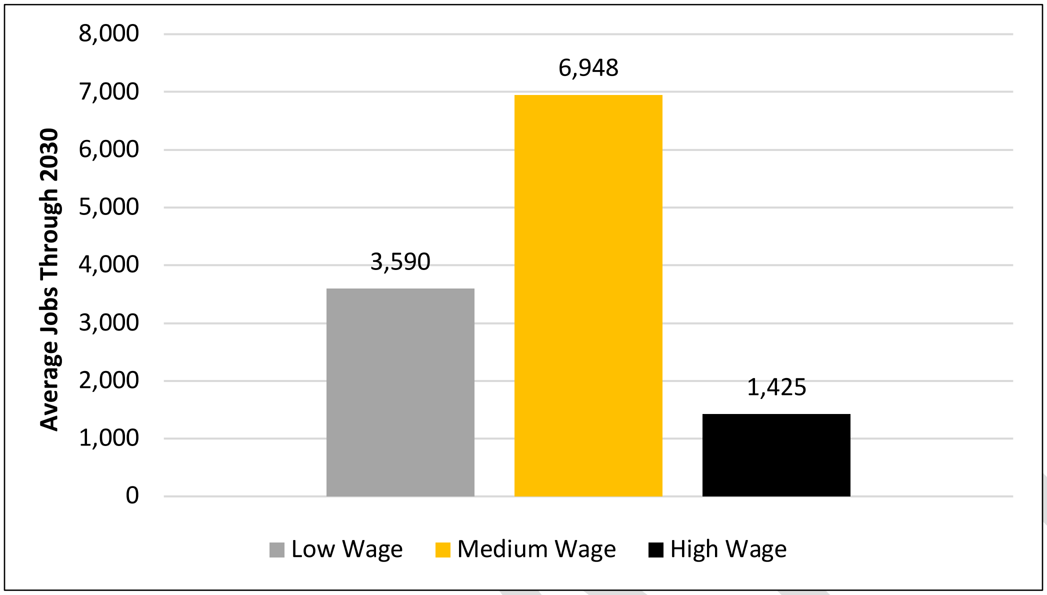


Sources: E3, MDE, O*Net, REMI, RESI

Simulations for the Draft GGRA Plan indicate robust job growth for occupations in Job Zones 2 and 3, where jobs typically require modest preparation and a high school diploma (Job Zone 2), or an associate degree or vocational training (Job Zone 3). This is beneficial in that retraining and educational needs are expected to be relatively less extensive and time consuming. No negative impacts are seen in any job zone under the Draft GGRA Plan, with the smallest annual increases represented in Job Zones 1 and 5.

Figure 18 illustrates employment results by wage group, as previously outlined in Section 1.4.3.1.

Figure 18: Employment by Wage Group for Draft GGRA Plan

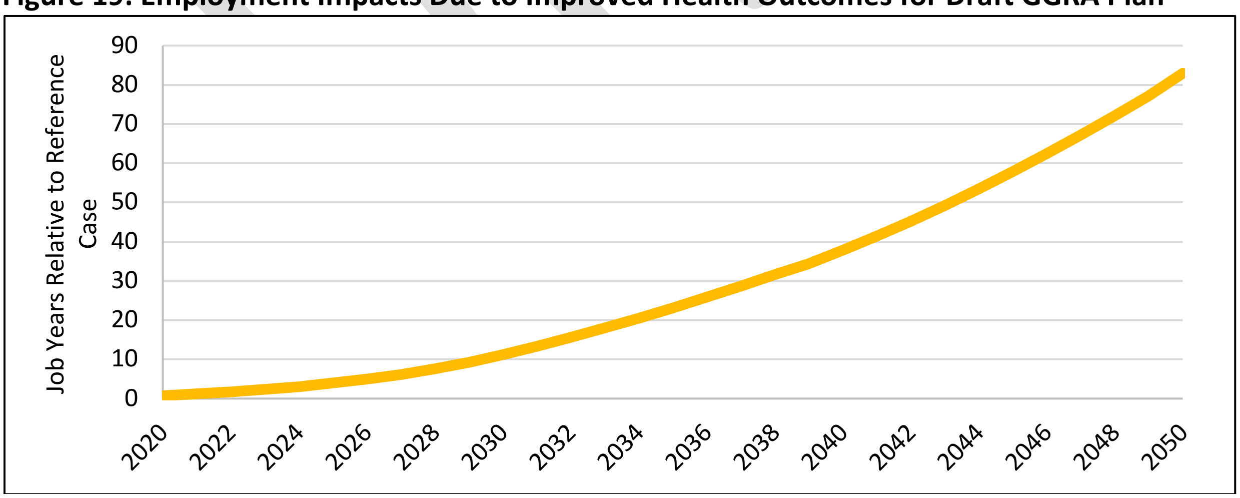


Sources: E3, MDE, REMI, RESI, U.S. BLS

Over half of the employment impacts under the Draft GGRA Plan, 6,948 jobs, are found in medium-wage occupations earning between $35,000 and $65,000 annually. This is followed by an annual average of 3,590 jobs in the low wage category. Under this plan, high-wage positions experience the smallest impact.

Figure 19 details the expected employment impacts resulting from changes in health outcomes, as described in Section 1.4.3.1.

Figure 19: Employment Impacts Due to Improved Health Outcomes for Draft GGRA Plan



Sources: E3, MDE, MDOT, RESI, U.S. EPA

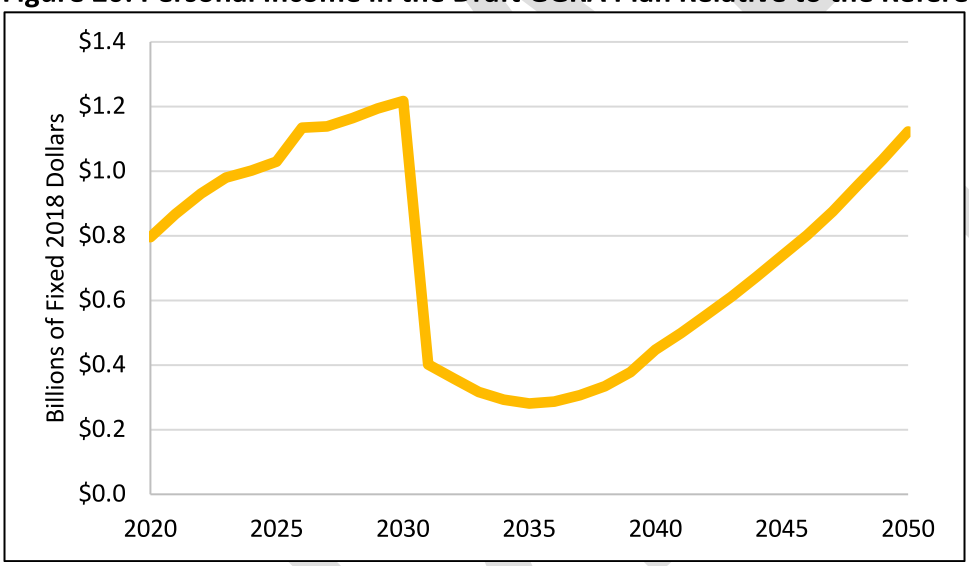
As illustrated above, the number of jobs due to improved health outcomes from the Draft GGRA Plan grows exponentially, averaging approximately 5 jobs per year through 2030 and 29 jobs per year through 2050. By 2050, an estimated 50 jobs will be created as a result of this Plan. This exponential growth is due to the cumulative effects of air pollution reduction. Detailed results for health impacts are found in Appendix C.5.

1.4.4 Personal Income in the Draft GGRA Plan

In addition to employment, it is also important to consider how personal income will be affected. Personal income within REMI is calculated as the sum of the total wages and salaries, supplements to these wages and salaries, property income, and personal current transfer receipts. Of these, wages and salaries represent the majority of personal income in Maryland.

The Draft GGRA Plan posts an increase averaging $1.0 billion between 2020 and 2030. The Draft GGRA Plan also shows a decline after 2030 due to the transportation projects, but fuel savings outweigh any capital expenditures in the long run. Even during the decline, personal income remains positive relative to the reference case in every year.

Figure 20: Personal Income in the Draft GGRA Plan Relative to the Reference Case



Sources: REMI, E3, MDE, MDOT, RESI

1.4.5 Gross State Product (GSP) in the Draft GGRA Plan

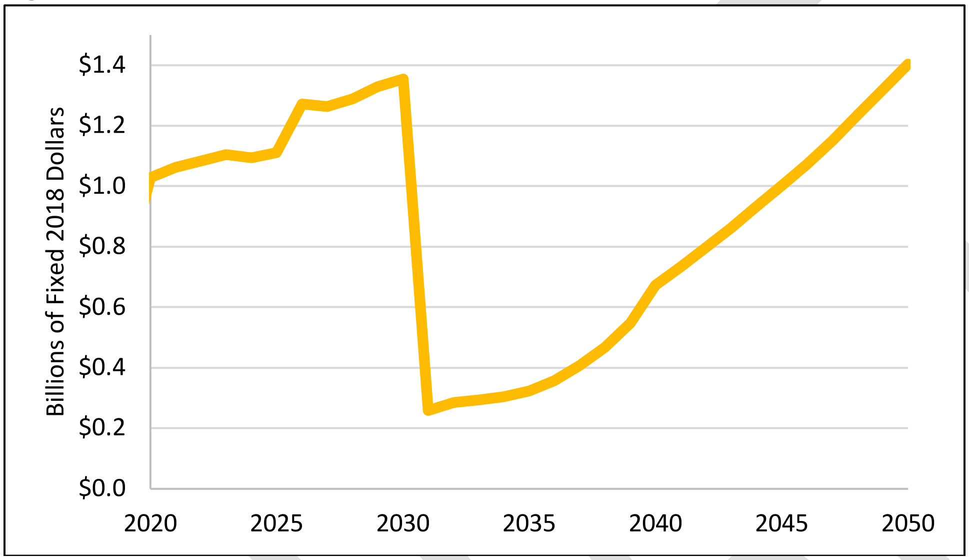
The Project Team also considered impacts to Maryland's economy measured as changes to gross state product (GSP), which is the sum of consumption, investment, government expenditures, and net exports for the state. In 2017, Maryland's GSP totaled nearly $400 billion dollars.[30] The Project Team considered impacts to 2030 as well as between 2030 and 2050. To capture impacts over time, the Project Team measured dollars over time using cumulative net

[30] "Total Gross Domestic Product for Maryland (MDNGSP)," FRED Federal Reserve Bank of St. Louis, last modified November 19, 2018, accessed February 14, 2019, https://fred.stlouisfed.org/series/MDNGSP.

present value, a common way of comparing the return on investment when looking at the financial viability of multiple projects or policies over a period of time.

For this analysis, the Project Team used a discount rate of 3 percent, with contributions to GSP remaining positive through 2030.[31] The Draft GGRA Plan adds an additional $11.2 billion to the state's GSP.

Figure 21: Gross State Product in the Draft GGRA Plan Relative to the Reference Case



Sources: REMI, E3, MDE, MDOT, RESI

Notably, the Draft GGRA Plan is forecasted to continue the positive trend through 2050. That is, Maryland will continue adding more jobs each year through 2050. Figure 21 illustrates the difference in GSP levels between the Draft GGRA Plan and the reference case.

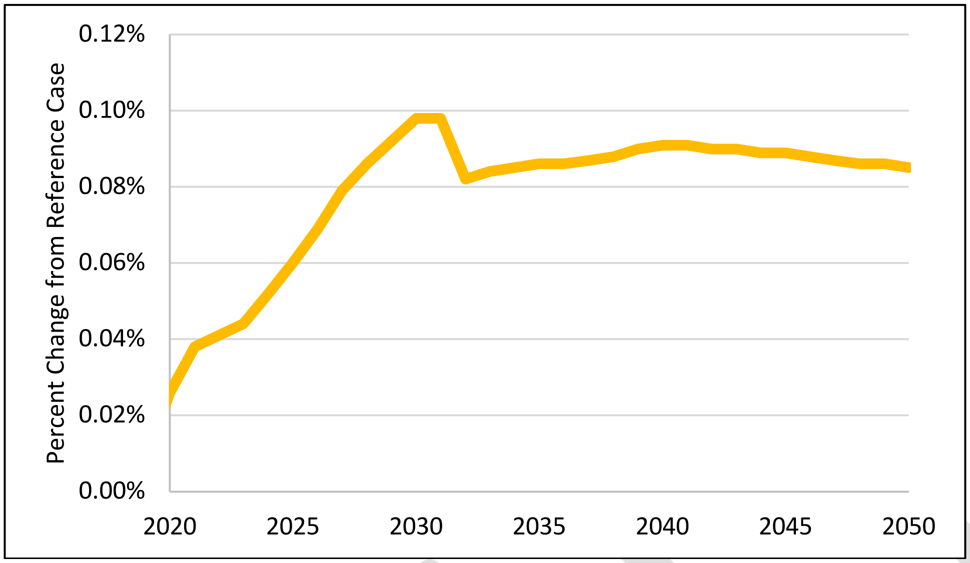
1.4.6 Consumer Prices in the Draft GGRA Plan

The Project Team also considered how the policy scenarios could impact the prices that Maryland residents would pay for goods and services. To do so, price changes were analyzed using the Personal Consumption Expenditure (PCE) Price Index relative to the reference case. The PCE Price Index, similar to the Consumer Price Index (CPI), measures the change in prices for a basket of goods. While the CPI asks consumers directly how much they spend, the PCE Price Index uses sales data from businesses to construct the index.

On average, as illustrated in Figure 22, the Draft GGRA Plan shows price increases through 2030, increasing from 0.06 to 0.08 percent relative to the reference case through 2030 and 2050, respectively.[32]

[31] Figures represent scenarios that include MDOT project spending.
[32] Figures represent scenarios that include MDOT project spending.

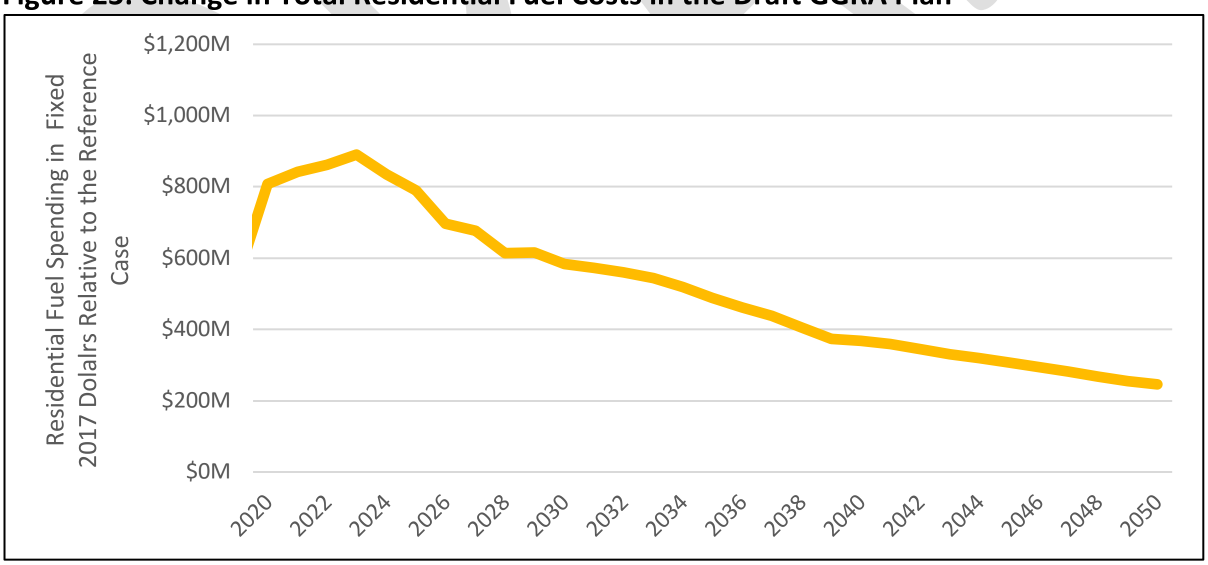
Figure 22: Percent Change in PCE Index in the Draft GGRA Plan Relative to the Reference Case



Sources: REMI, E3, MDE, MDOT, RESI

In addition to considering the impacts on overall consumer prices, the Project Team considered how the policy scenarios could affect the total cost of fuel for residential customers. A number of policies in the Draft GGRA Plan will affect the price and consumption of various fuels, leading to changes in total costs. Figure 23 details the projected change in residential fuel costs until 2050 for the Draft GGRA Plan.

Figure 23: Change in Total Residential Fuel Costs in the Draft GGRA Plan



Source: E3, MDE, REMI, RESI

In 2030, residential spending on non-transportation utilities is higher than the reference case in the Draft GGRA Plan. While this declines by 2050, residential spending in the Draft GGRA Plan remains higher than the reference case. In the GGRA Plan, spending on electricity increases, due to the increased cost of generation, as well as the increased usage of electricity instead of other fuels. Usage of electricity increases as consumers convert to using more energy efficient appliances. Natural gas spending also drops in the Draft GGRA Plan.

1.5 MWG Scenario Results

This section provides an overview of the MWG Scenario. The results of this policy were then examined. For more detail on individual assumptions and policies in all policy scenarios, please see Appendix A.

1.5.1 MWG Scenario Overview

The MWG Scenario consists of policies identified by the Mitigation Working Group (MWG) to achieve deeper emissions reductions. In addition to the continued adoption of the CARES target of 100 percent renewable energy by 2040, as well as meeting 100 percent reductions from the RGGI cap by 2040, these policies target additional sectors of the economy.

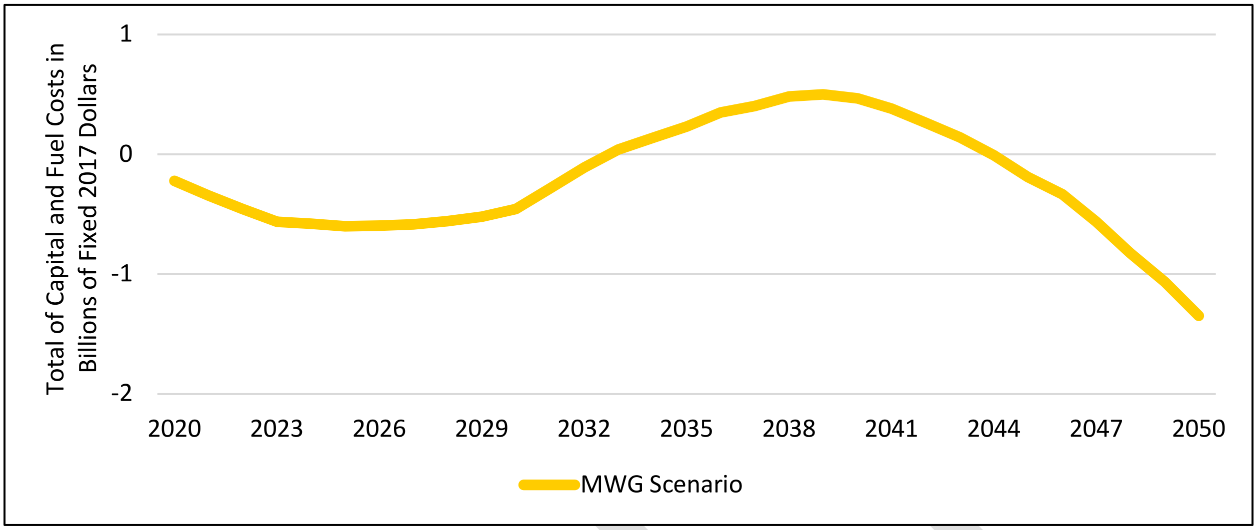
- For electrification and efficiency gains in buildings, this includes 95 percent of new heat pump sales by 2050 and 100 percent high efficiency electric appliance sales by 2030.
- In the transportation sector, 800,000 additional zero emissions light duty vehicles will be sold (compared to the reference case) with this total rising to 5 million by 2050. For heavy duty vehicles, it is assumed that 40 percent of sales by 2030 will be electric or diesel hybrid vehicles. By 2050, this grows to 95 percent. MDOT plans to achieve 100 percent electrification of transit busses and construction vehicles by 2050 and 2040, respectively.

The following sections contain the economic results of the MWG Scenario.

1.5.2 Spending and Electricity Demand in the MWG Scenario

Similar to the Draft GGRA Plan, the interplay between capital expenditures and fuel costs is a large factor in determining the economic outcomes. Economy-wide, when capital expenditures offset fuel savings, this produces negative economic results. On the other hand, when fuel savings are able to overcompensate for any increases in capital expenditures, this is a benefit to the economy. As seen below in Figure 24, costs in the MWG Scenario increase relative to the reference case from 2033 to 2043, but remain below the reference case in all other years of the model.

Figure 24: Total Costs from PATHWAYS for the MWG Scenario Relative to the Reference Case

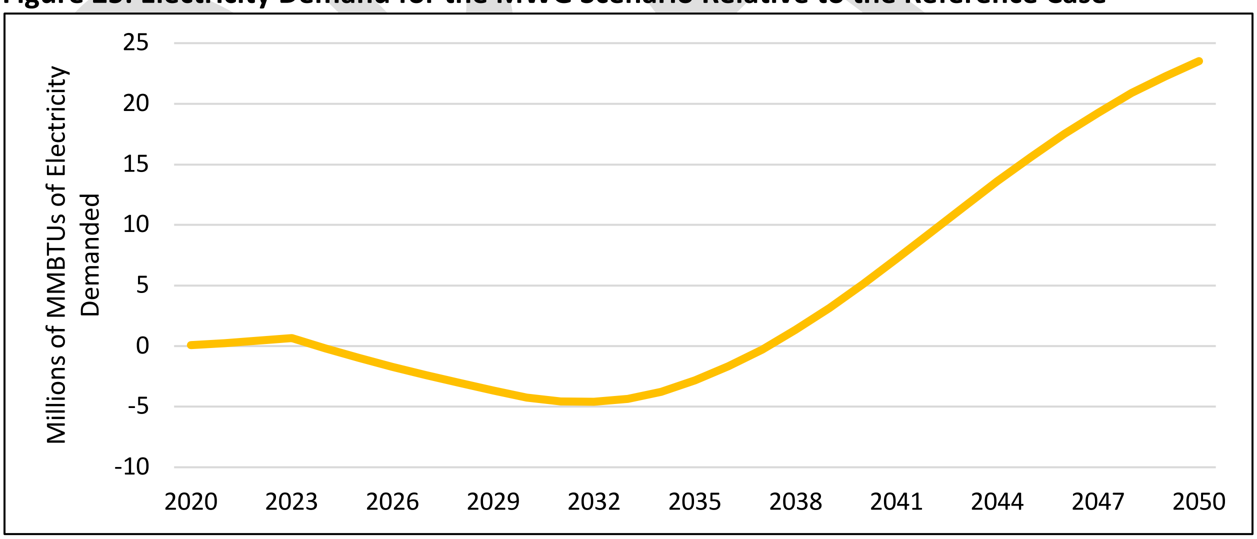


Sources: E3, MDE, RESI

When total costs are below zero, this means that capital expenditures are being offset by fuel savings. This is observed in the period before 2030. After 2030 through the mid-2040s, fuel savings do not outweigh expenditures on capital.

While electricity demand starts off slowly in the MWG Scenario, in 2038 demand begins to exceed reference case levels, as seen below.

Figure 25: Electricity Demand for the MWG Scenario Relative to the Reference Case



Sources: E3, MDE, RESI

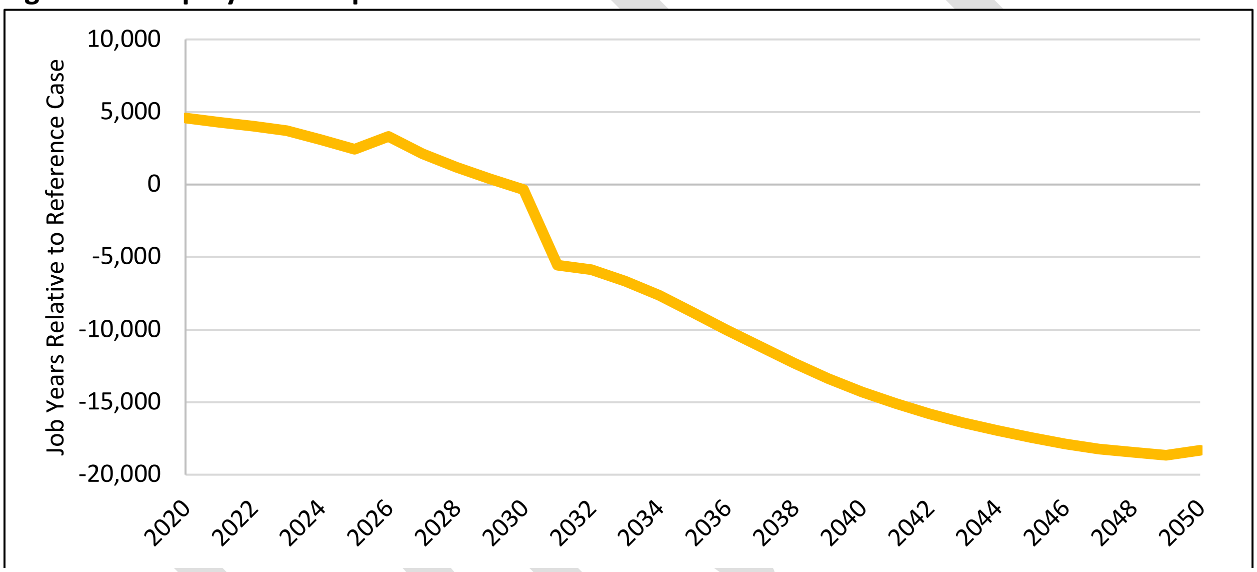
1.5.3 Employment

To meet the economic goals as described in Section 1.3.7, policy scenarios must achieve positive job growth, on average, through 2030. This section presents detailed employment results for each policy scenario. Employment in the MWG Scenario is measured along the same dimensions as in the Draft GGRA Plan in Section 1.4.3.1.

On average, the MWG Scenario supports approximately 2,624 jobs annually through 2030. These impacts largely result from transportation strategies implemented by MDOT. Specifically, transportation programs such as Intermodal Freight Centers Access Improvement and Transit Capacity/Service Expansion are responsible for a significant portion of the near-term transportation-related jobs.

Figure 26 shows employment changes in the MWG Scenario, with significant declines beginning after 2025. These drops in employment correspond with MDOT project timelines, most of which are forecasted to be completed by 2025, with some projects having an estimated completion date of 2030.

Figure 26: Employment Impacts of the MWG Scenario

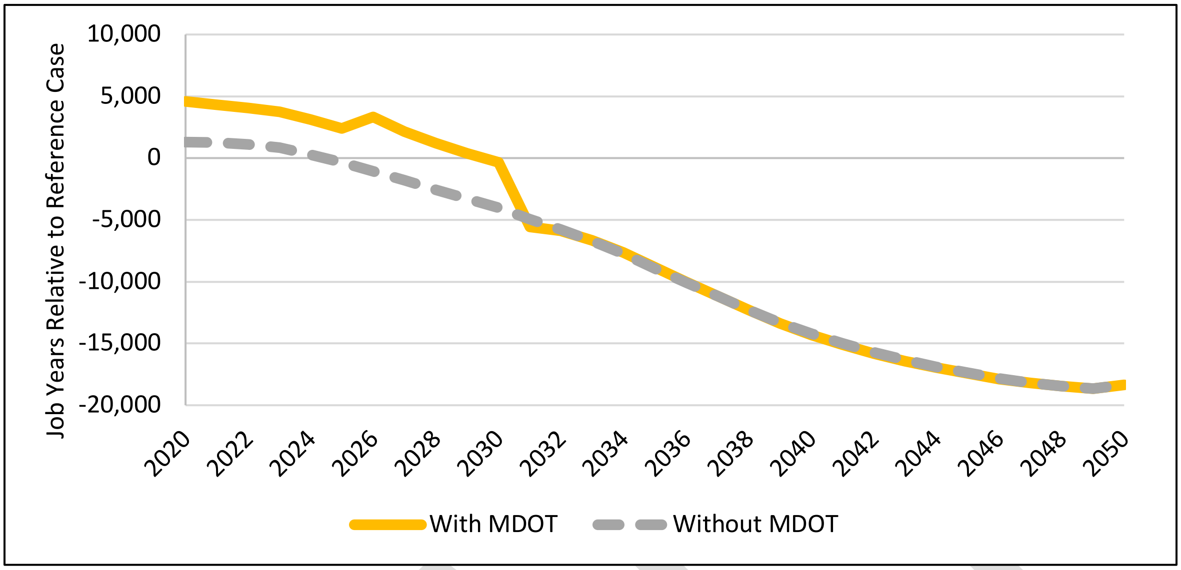


Sources: REMI, E3, MDE, MDOT, RESI

In the years beyond 2030, employment levels drop relative to the reference case. This is mainly due to the more aggressive emissions assumptions for the MWG Scenario. Consumers and businesses are spending more on capital relative to their fuel savings, producing a net cost to the economy. For example, if a consumer invests in a high efficiency air conditioner but the fuel savings do not overcompensate for the additional cost of the purchase (compared to a standard air conditioner).

Figure 27 shows the difference in employment effects with and without funding directed towards transportation measures.

Figure 27: Employment Impacts due to Transportation Measures for MWG Scenario

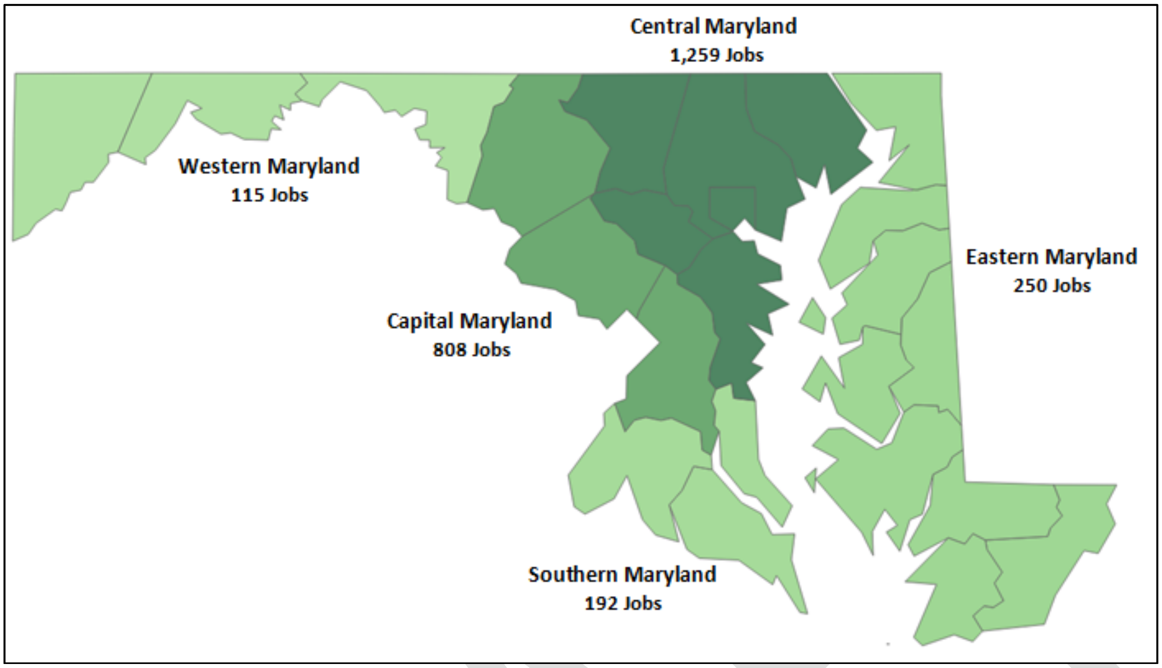


Sources: REMI, E3, MDE, MDOT, RESI

There is divergence in the near-term between the scenarios with and without MDOT projects. The effects become virtually identical after 2030 as the MDOT measures are set to expire. On average through 2030, the scenario without MDOT spending supports 3,382 fewer jobs annually compared to the scenario with MDOT spending. By 2030, both scenarios are forecasted to support fewer jobs than would exist under the reference case.

Figure 28 shows the regional distribution of jobs under the MWG Scenario, with darker-shaded areas having greater average employment gains through 2030.

Figure 28: Average Annual Employment Impacts by Region for MWG Scenario, 2020-2030



Sources: E3, MDE, RESI

Central Maryland shows the largest gains with 1,259 jobs, followed by Capital Maryland with 808 jobs. Job gains in the other regions are modest, with average annual employment impacts of 250 jobs or less in each region.

Employment distributions by major NAICS industries are outlined in Figure 29. As shown below, Construction is responsible for more than 100 percent of the total jobs supported by the MWG Scenario, offsetting job losses seen in a number of other industries.

Figure 29: Employment Impacts by Industry for the MWG Scenario, 2020-2030

NAICS	Industry	Annual Average Number of Jobs, 2020-2030
11	Agriculture, Forestry, Fishing and Hunting	140
21	Mining, Quarrying, and Oil and Gas Extraction	-69
22	Utilities	-132
23	Construction	3,287
31-33	Manufacturing	108
42	Wholesale Trade	-45
44-45	Retail Trade	-935
48-49	Transportation and Warehousing	14
51	Information	-9
52	Finance and Insurance	10
53	Real Estate and Rental and Leasing	-21

54	Professional, Scientific, and Technical Services	-31
55	Management of Companies and Enterprises	-12
56	Administrative and Support and Waste Management and Remediation Services	-8
61	Educational Services	20
62	Health Care and Social Assistance	184
71	Arts, Entertainment, and Recreation	-3
72	Accommodation and Food Services	25
81	Other Services (except Public Administration)	74
92	Public Administration	29
Total		**2,624**

Sources: E3, MDE, REMI, RESI, U.S. Census

Job losses are seen in the same number of industries that experience job growth. The largest loss is seen in Retail Trade, which loses an annual average of 935 jobs between 2020 and 2030, as the need for gas stations falls with increased electric vehicle use.

The occupational distributions of employment changes within the MWG Scenario are detailed in Figure 30.

Figure 30: Employment Impacts by Occupation for MWG Scenario

SOC Code	SOC Description	Annual Average Number of Jobs, 2020-2030
11	Management Occupations	179
13	Business and Financial Operations Occupations	86
15	Computer and Mathematical Occupations	-10
17	Architecture and Engineering Occupations	28
19	Life, Physical, and Social Science Occupations	-3
21	Community and Social Service Occupations	14
23	Legal Occupations	-4
25	Education, Training, and Library Occupations	29
27	Arts, Design, Entertainment, Sports, and Media Occupations	-9
29	Healthcare Practitioners and Technical Occupations	22
31	Healthcare Support Occupations	33
33	Protective Service Occupations	1
35	Food Preparation and Serving Related Occupations	-9
37	Building and Grounds Cleaning and Maintenance Occupations	21
39	Personal Care and Service Occupations	55
41	Sales and Related Occupations	-444

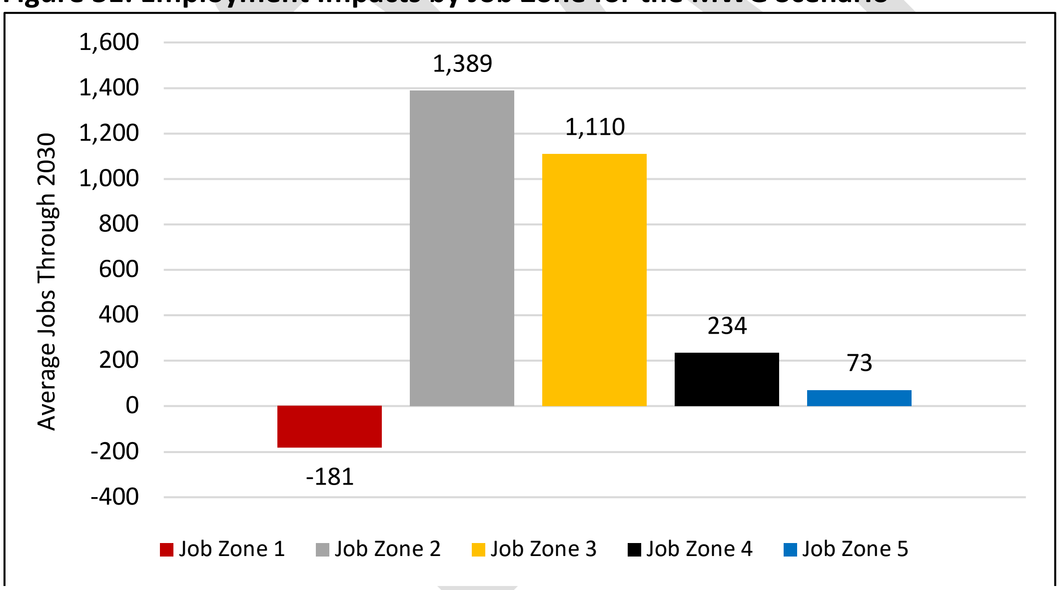
43	Office and Administrative Support Occupations	138
45	Farming, Fishing, and Forestry Occupations	76
47	Construction and Extraction Occupations	2,044
49	Installation, Maintenance, and Repair Occupations	230
51	Production Occupations	76
53	Transportation and Material Moving Occupations	72
Total		**2,624**

Sources: E3, MDE, REMI, RESI, U.S. BLS

In the MWG Scenario, Construction and Extraction Occupations post the largest gains at 2,044 jobs on average through 2030, followed distantly by Installation, Maintenance, and Repair Occupations with an annual average impact of 230 jobs. A number of occupational groups experience little-to-no impact under this scenario. One occupational group, Sales and Related Occupations, shows a more significant average annual loss in jobs relative to the reference case. This annual negative impact of 444 jobs is the second-largest impact among all occupations in absolute terms.

Figure 31 provides annual employment impacts for each of the five job zones defined in Section 1.4.3.1.

Figure 31: Employment Impacts by Job Zone for the MWG Scenario

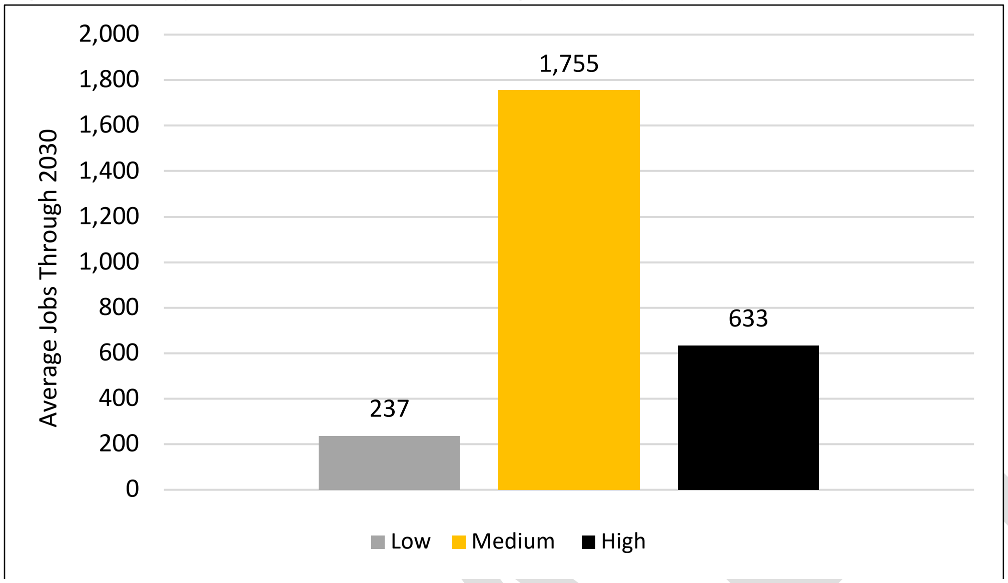


Sources: E3, MDE, O*Net, REMI, RESI

The simulation results for the MWG Scenario show that the largest employment gains will be in Job Zone 2 and Job Zone 3. Job gains in zones that require less education or training may help to increase the labor force participation rate in the state, as these jobs have fewer barriers to entry. Under this plan, jobs with the absolute lowest barrier to entry (Job Zone 1) experience a net loss in jobs relative to the reference case.

Employment distributions by wage group for the MWG Scenario are illustrated in Figure 32.

Figure 32: Employment Impacts by Wage Group for MWG Scenario

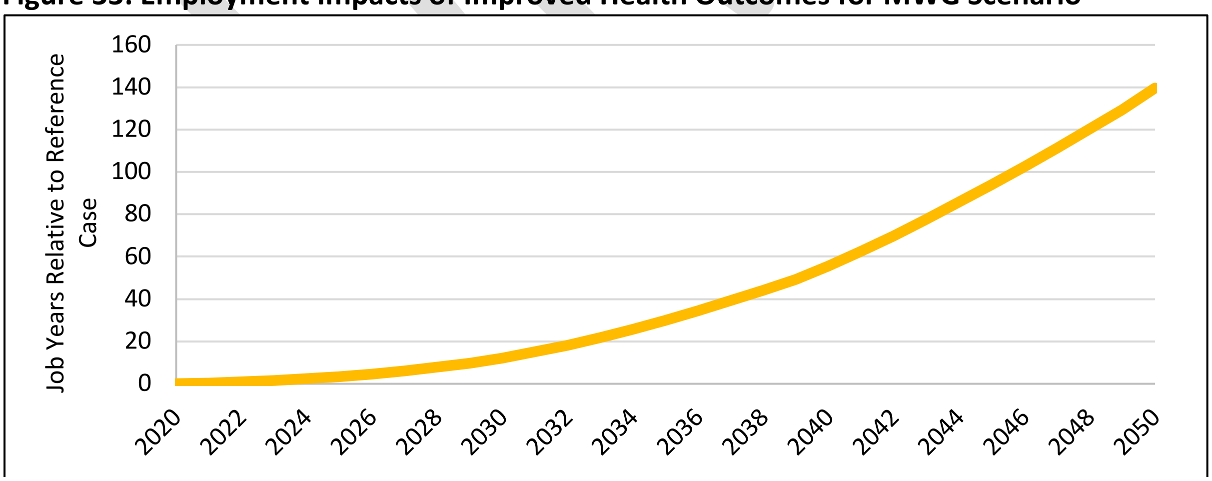


Sources: E3, MDE, REMI, RESI, U.S. BLS

Medium-wage occupations show the largest gains under the MWG Scenario. Similar to the Draft GGRA Plan, the MWG Scenario also supports fewer low- and high-wage jobs. Unlike the Draft GGRA Plan, new high-wage jobs outnumber new low wage-jobs. This is likely due to the larger proportion of jobs in Office and Administrative Support occupations. These occupations are likely supported by the strong job gains in the construction industry.

The employment impacts due to improved health outcomes for the MWG Scenario are illustrated in Figure 33.

Figure 33: Employment Impacts of Improved Health Outcomes for MWG Scenario



Sources: E3, MDE, MDOT, RESI, U.S. EPA

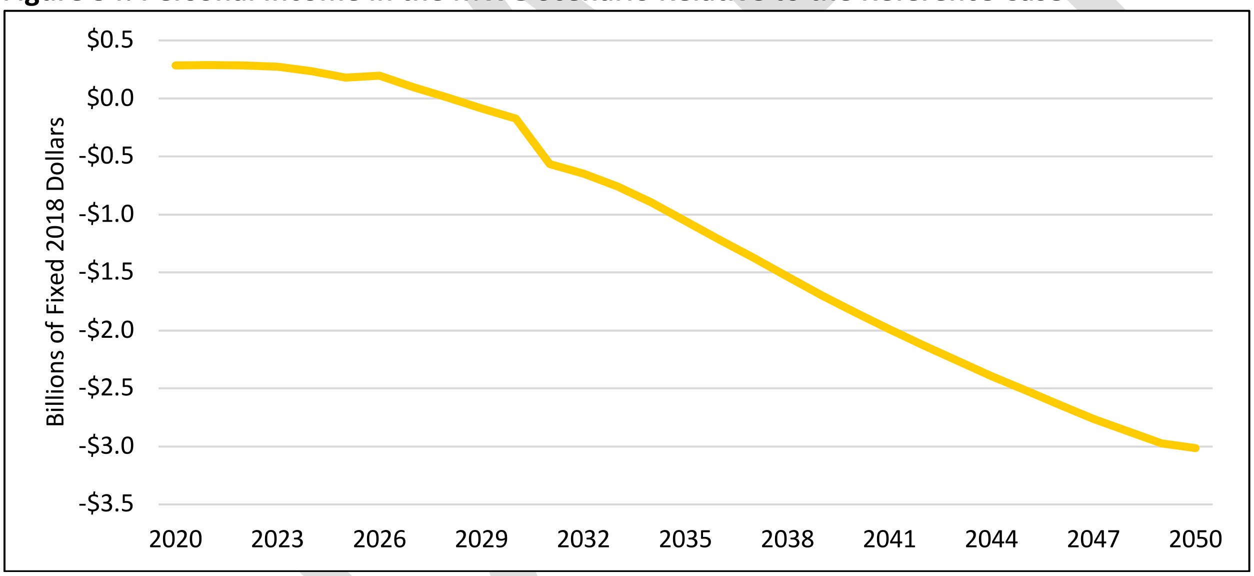
Notably, because emissions reductions are more substantial in the MWG Scenario, the magnitude of job gains resulting from health improvements are larger, supporting an average of four jobs through 2030 and 44 jobs through 2050. Detailed results for health impacts are found in Appendix C.5.

1.5.3 Personal Income in the MWG Scenario

In addition to employment, it is also important to consider how personal income will be affected. Personal income within REMI is calculated as the sum of the total wages and salaries, supplements to these wages and salaries, property income, and personal current transfer receipts. Of these, wages and salaries represent the majority of personal income in Maryland.

The MWG Scenario shows gains of $0.1 billion on average through 2030.[33] As illustrated in Figure 34, the trends over time vary considerably by policy scenario. The MWG Scenario shows a large decrease in personal income after 2030, due to a combination of the expiration of MDOT transportation projects, as well as the increased expenditures on capital relative to fuel savings.

Figure 34: Personal Income in the MWG Scenario Relative to the Reference Case



Source: E3, MDE, REMI, RESI

1.5.4 Gross State Product (GSP) in the MWG Scenario

The Project Team also considered impacts to Maryland's economy measured as changes to gross state product (GSP), which is the sum of consumption, investment, government expenditures, and net exports for the state. In 2017, Maryland's GSP totaled nearly $400 billion dollars.[34] The Project Team considered impacts to 2030 as well as between 2030 and 2050. To

[33] Figures represent scenarios that include MDOT project spending.

[34] "Total Gross Domestic Product for Maryland (MDNGSP)," FRED Federal Reserve Bank of St. Louis, last modified November 19, 2018, accessed February 14, 2019, https://fred.stlouisfed.org/series/MDNGSP.

capture impacts over time, the Project Team measured dollars over time using cumulative net present value, a common way of comparing the return on investment when looking at the financial viability of multiple projects or policies over a period of time.

For this analysis, the Project Team used a discount rate of 3 percent.

Figure 35: Cumulative Net Present Value

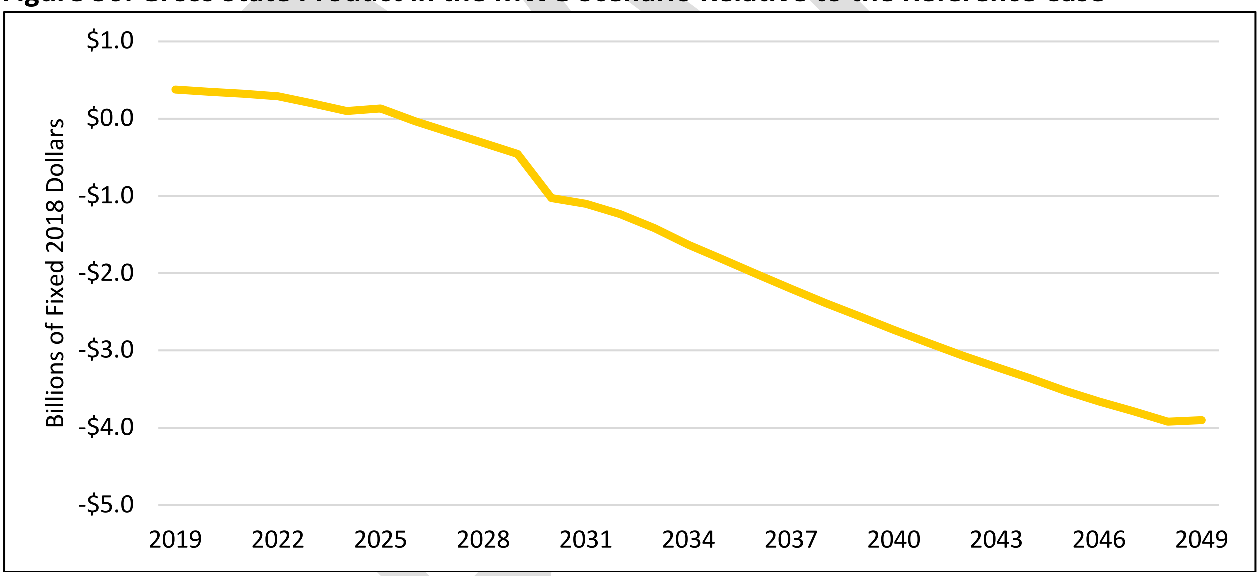
	MWG Scenario
2020 Through 2030	$926,166,774
2030 Through 2050	-$25,769,002,909

Sources: E3, MDE, REMI, RESI

Contributions to GSP remain positive through 2030.[35] The MWG Scenario sees gains of $0.9 billion to the state's GSP through 2030 but drops negative through 2050. Note that this negative GSP does not imply an economic contraction (i.e., economic growth remains positive in all years), but is negative relative to the reference case.

Figure 36 below details changes to Maryland's GSP under both scenarios through 2050.

Figure 36: Gross State Product in the MWG Scenario Relative to the Reference Case



Sources: E3, MDE, REMI, RESI

Changes to Maryland's GSP are forecasted to be positive through 2025 in the MWG Scenario but decline in subsequent years, relative to the reference case.

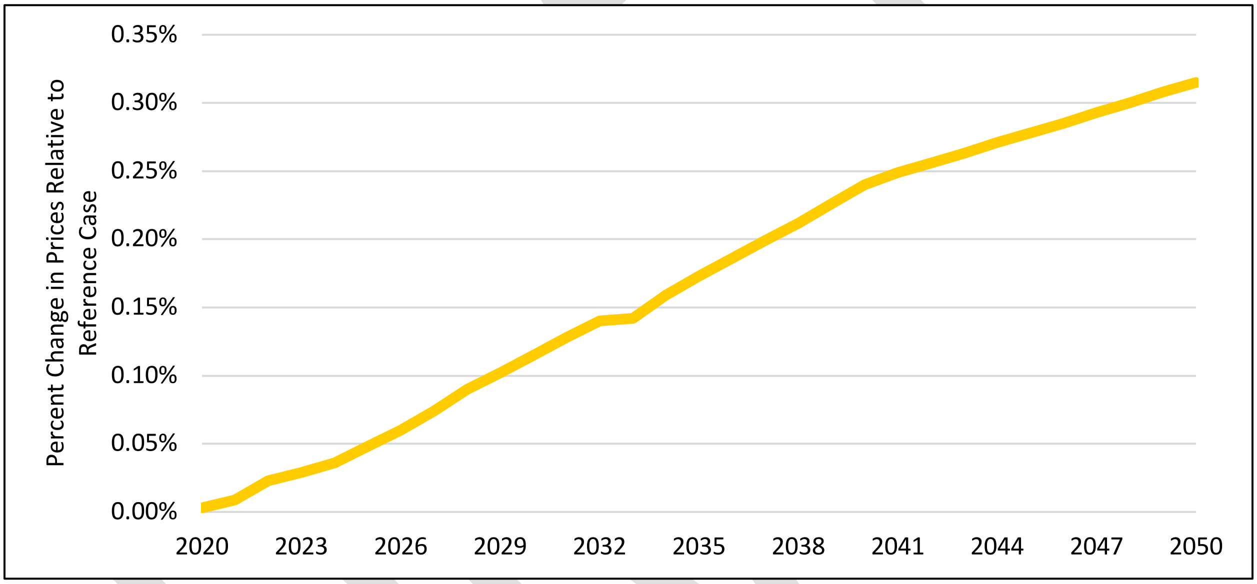
[35] Figures represent scenarios that include MDOT project spending.

1.5.5 Consumer Prices in the MWG Scenario

The Project Team also considered how the policy scenarios could impact the prices that Maryland residents would pay for goods and services. To do so, price changes were analyzed using the Personal Consumption Expenditure (PCE) Price Index relative to the reference case. The PCE Price Index, similar to the Consumer Price Index (CPI), measures the change in prices for a basket of goods. While the CPI asks consumers directly how much they spend, the PCE Price Index uses sales data from businesses to construct the index.

On average, as illustrated in Figure 37, the MWG Scenario shows price increases of 0.08 percent relative to the reference case on average through 2030.[36] After 2030, the MWG Scenario continues to show a rise in consumer prices, averaging a 0.18 percent increase through 2050.

Figure 37: Change in the PCE Price Index in the MWG Scenario

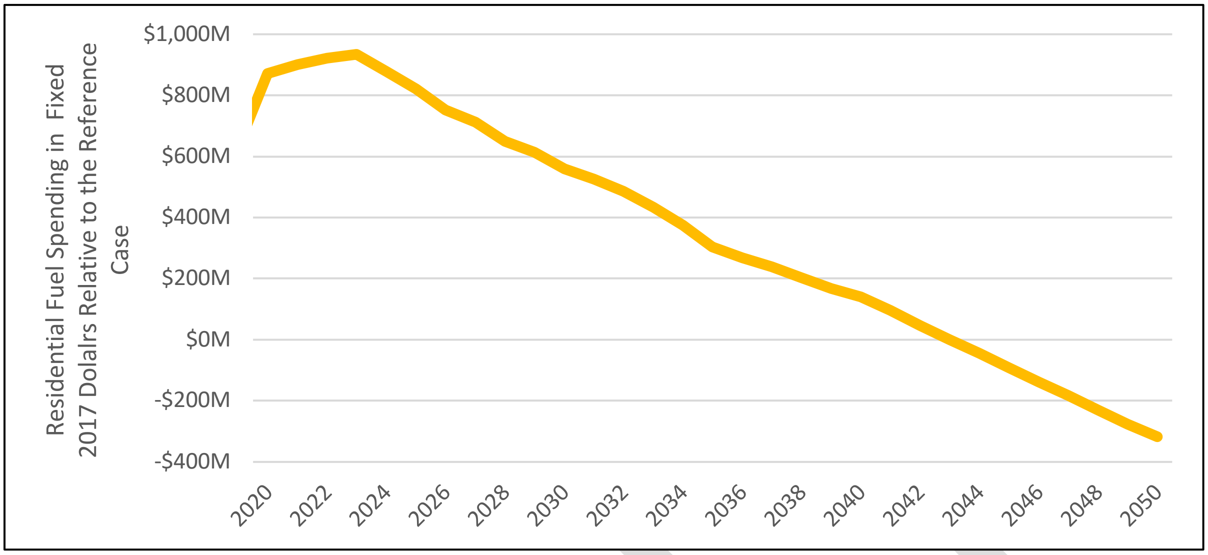


Sources: E3, MDE, REMI, RESI

In addition to considering the impacts on overall consumer prices, the Project Team considered how the policy scenarios could affect the total cost of fuel for residential customers. A number of policies in the MWG Scenario will affect the price and consumption of various fuels, leading to changes in total costs. Figure 38 details the projected change in residential fuel costs until 2050 for the MWG Scenario.

[36] Figures represent scenarios that include MDOT project spending.

Figure 38: Change in Total Residential Fuel Costs in the MWG Scenario



Source: E3, MDE, REMI, RESI

In 2030, residential spending on non-transportation utilities is higher than the reference case in the MWG Scenario. However, by 2050, residential spending in the MWG Scenario is lower than the reference case. In the MWG Scenario, spending on electricity increases, due to the increased cost of generation, as well as the increased usage of electricity instead of other fuels. Usage of electricity increases as consumers convert to using more energy efficient appliances. Natural gas spending drops in MWG Scenario.

1.6 Final GGRA Plan

After the emissions and economic impacts associated with the Draft GGRA Plan and the MWG Scenario were estimated and analyzed, the Final GGRA Plan was constructed both to achieve the emissions requirements laid forth in the GGRA and provide a blueprint for future efforts to reduce greenhouse gas emissions. Compared to the MWG Scenario, this plan contains marginally less aggressive policies in some sectors, including electrification and increased efficiency in buildings, transportation (including both light duty and heavy-duty vehicle sales), and industrial energy use. On the other hand, compared to the Draft GGRA Plan, the final plan contains significantly more aggressive measures in those sectors.

1.6.1 Policy Scenario Four Results

Similar to the Draft GGRA Plan and the MWG Scenario, the Final GGRA Plan meets the economic goals outlined in Section 1.3.7. As shown in Figure 39, all policy scenarios achieve the 2030 economic goals and meet both the 2020 and 2030 emissions targets.

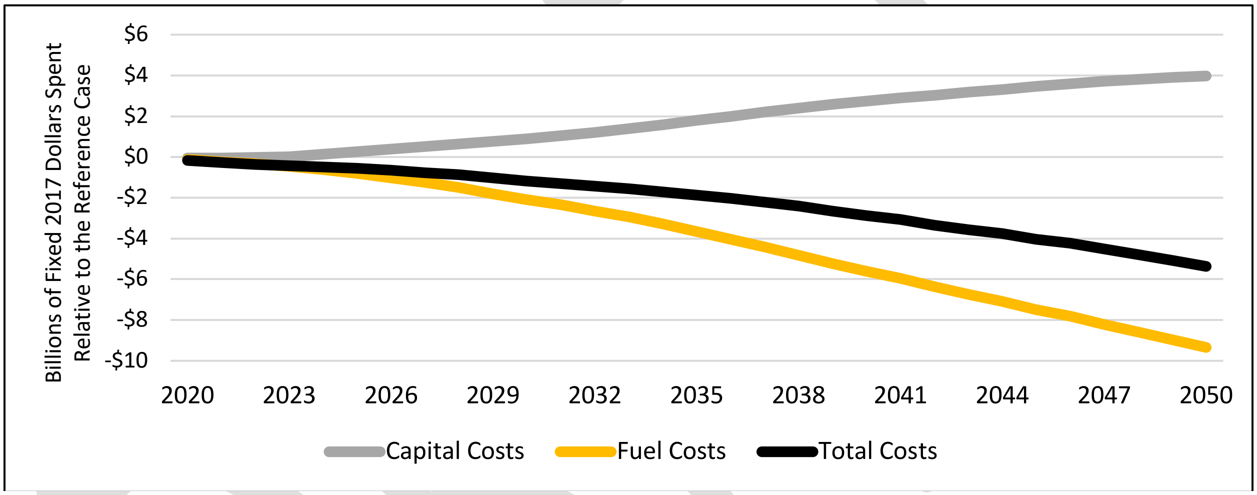
Figure 39: Summary of Policy Scenarios

Policy Scenario	Achieve 2020 Emissions Goal?	Achieve 2030 Emissions Goal?	Achieve 2030 Economic Goal?
Draft GGRA Plan	Yes	Yes	Yes
MWG Scenario	Yes	Yes	Yes
Final GGRA Scenario	Yes	Yes	Yes

Source: RESI

Notably, the Final GGRA Plan achieves these goals with low levels of spending. As illustrated in Figure 40, for every year of the Final GGRA Plan, consumers and businesses spend less on total costs (capital costs plus fuel costs) relative to the reference case.

Figure 40: Total Costs from PATHWAYS in the Final GGRA Plan Relative to the Reference Case



Sources: E3, MDE, RESI

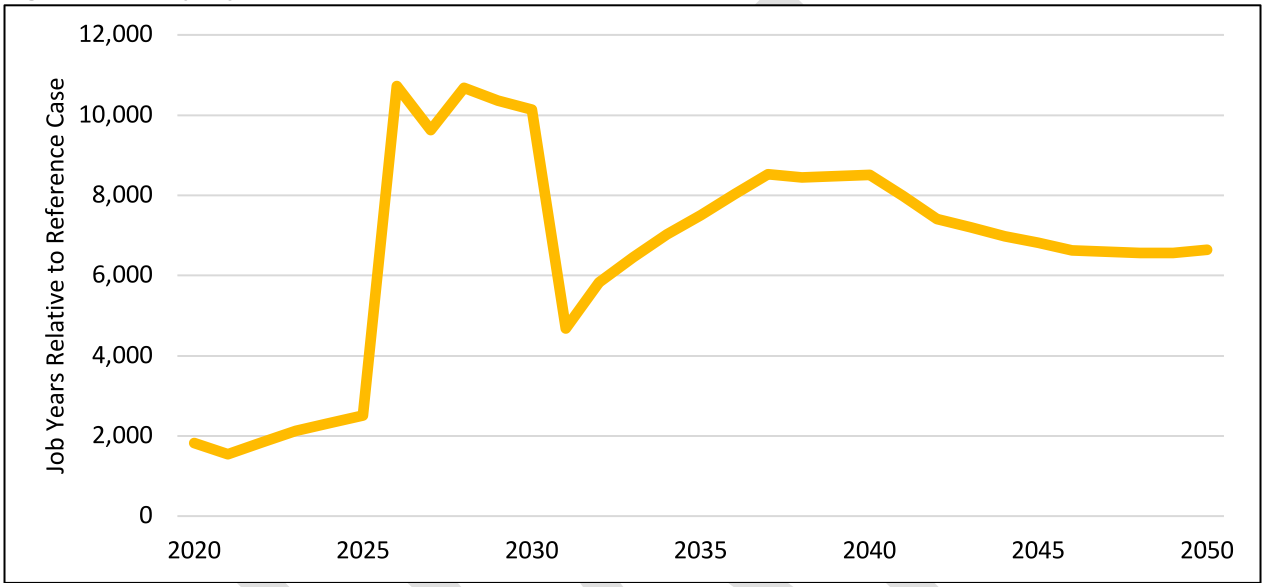
As seen in Figure 40, although consumers and businesses are spending more on capital costs (e.g., new energy-efficient appliances or new electric vehicles) in the Final GGRA Plan than in the reference case, fuel savings exceed this amount every year. This result is attributable to two general trends.

1. Spending on transportation infrastructure projects is significant in the Final GGRA Plan. These projects are generally due to policies aimed at reducing fuel usage through behavioral changes (e.g., increased mass transit usage or increased use of bike lanes), as well as more direct capital outlays (e.g., truck stop electrification or transit bus electrification).
2. Total costs are generally the lowest when compared to the Draft GGRA Plan and the MWG Scenario. In both the Draft GGRA Plan and the MWG Scenario, total costs increase post-2030 before eventually declining. The Final GGRA Plan has a consistent decline in costs through 2050.

1.6.1.1 Employment in the Final GGRA Plan

The impacts of infrastructure spending, capital/fuel costs, and renewable energy generation can all be seen when examining the economic impacts of the Final GGRA Plan. As seen in Figure 41, the Final GGRA Plan supports an average of 5,788 jobs each year through 2030 relative to the reference case.

Figure 41: Employment in the Final GGRA Plan Relative to the Reference Case

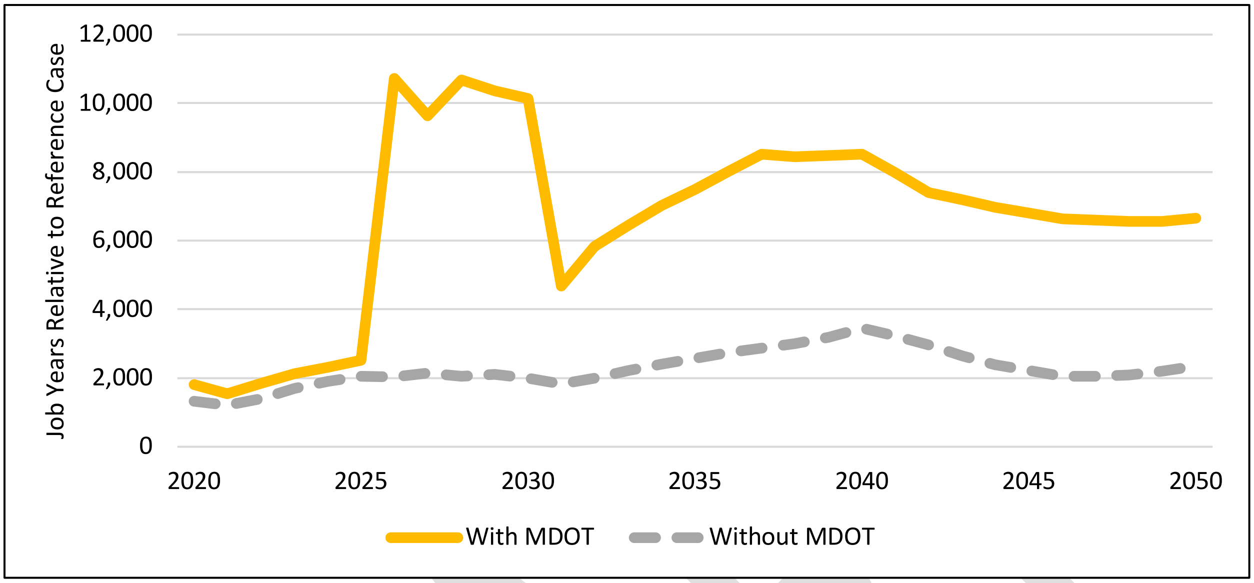


Sources: E3, MDE, REMI, RESI

Through 2030, transportation infrastructure projects largely drive employment impacts, as seen in other policy scenarios. After 2030, employment impacts remain positive relative to the reference case. The steady increase in employment after 2030 is due in part to the capital cost to fuel cost ratio, as well as the increased demand for state-produced renewable energy. Because total spending is lower, consumers have more money to spend on other goods and services, and businesses are profitable.

To visualize the impact of spending on transportation infrastructure on the economic impact results for the Final GGRA Plan, Figure 42 below shows employment differences under the scenario with and without this spending.

Figure 42: Employment in the Final GGRA Plan With and Without Transportation Spending Relative to the Reference Case

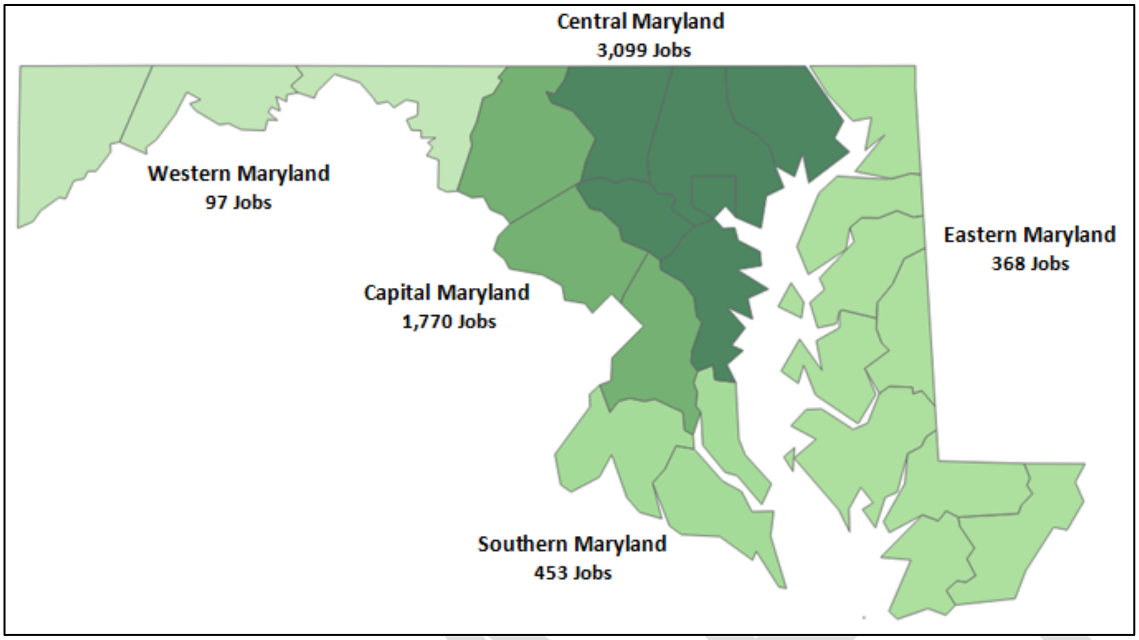


Sources: E3, MDE, REMI, RESI

The impact of transportation spending in the Final GGRA Plan is similar to the impacts in the other policy scenarios. However, a methodological change for the Final GGRA Plan results in higher average job creation after 2030. Instead of assuming that all transportation investments end in 2030, the linear average of program costs is used to approximate future investment through 2050. On average through 2030, transportation infrastructure measures support 3,977 more jobs compared to the scenario without this spending. This is illustrated above as the difference between the two lines. Regardless of the status of the transportation spending, however, employment impacts are steadily positive for the Final GGRA Plan.

As shown in Figure 43, all regions of Maryland experience positive job growth relative to the reference case through 2030 for the Final GGRA Plan.

Figure 43: Employment Impacts by Region for Final GGRA Plan



Sources: E3, MDE, REMI, RESI

Following a similar pattern as with the other policy scenarios, Central Maryland sustains the largest employment gains of 3,099 jobs. The Capital Maryland region also shows significant employment increases of 1,770 jobs. Central, Eastern, and Southern Maryland have the most significant employment impact when adjusting for population, each gaining a number of annual jobs approximately equal to 0.1 percent of the region's population. Western Maryland adds jobs at only a quarter of that rate.

Figure 44 below details employment impacts under the Final GGRA Plan through 2030 by industry. Of the annual average of 5,788 jobs, the Construction industry comprises the majority of positions at 3,074 jobs and is driven largely by spending on transportation infrastructure policies during this period.

Figure 44: Employment Impacts by Industry for the Final GGRA Plan, 2020 Through 2030

NAICS	Industry	Annual Average Number of Jobs, 2020-2030
11	Agriculture, Forestry, Fishing and Hunting	134
21	Mining, Quarrying, and Oil and Gas Extraction	-12
22	Utilities	-111
23	Construction	3,074
31-33	Manufacturing	136
42	Wholesale Trade	55
44-45	Retail Trade	101
48-49	Transportation and Warehousing	-24
51	Information	28
52	Finance and Insurance	128
53	Real Estate and Rental and Leasing	150
54	Professional, Scientific, and Technical Services	278
55	Management of Companies and Enterprises	23
56	Administrative and Support and Waste Management and Remediation Services	156
61	Educational Services	60
62	Health Care and Social Assistance	573
71	Arts, Entertainment, and Recreation	68
72	Accommodation and Food Services	288
81	Other Services (except Public Administration)	349
92	Public Administration	334
Total		**5,788**

Sources: E3, REMI, RESI, U.S. Census Bureau

Under the Final GGRA Plan, the Health Care and Social Assistance and Other Services (except Public Administration) industries have the second- and third-highest average gains of 573 and 349 jobs, respectively. Employment decreases are seen in three industries, with the largest drop occurring in Utilities, which loses an average of 111 positions annually through 2030.

No occupational group is expected to have an annual decline under the Final GGRA Plan, as shown in Figure 45 below. The greatest impacts are seen in Construction and Extraction Occupations, with an increase of 1,940 jobs estimated annually through 2030.

Figure 45: Employment Impacts by Occupation for Final GGRA Plan

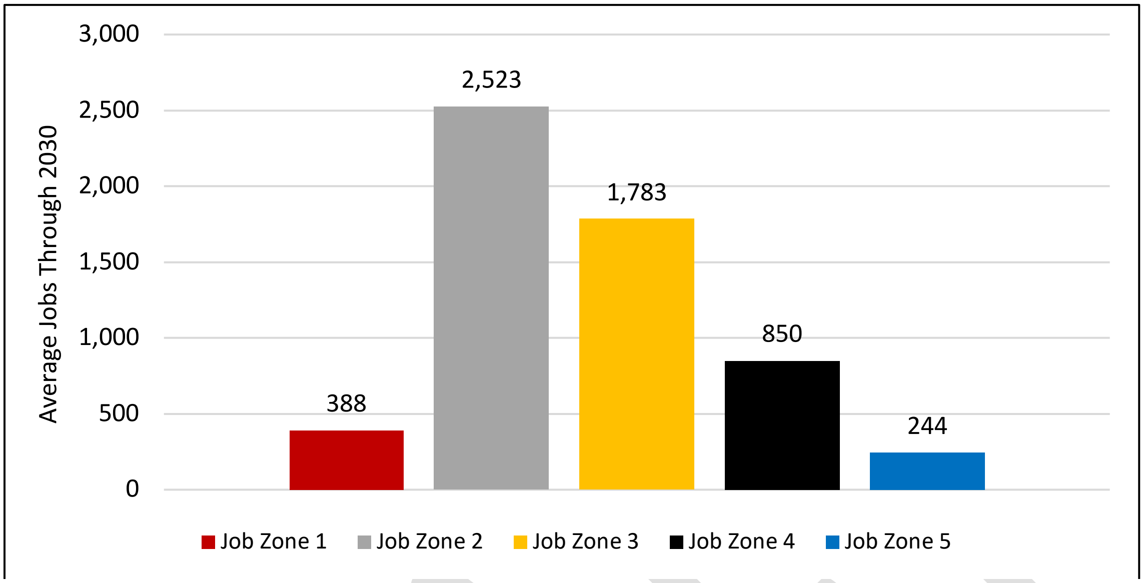
SOC Code	SOC Description	Average Jobs Through 2030
11	Management Occupations	339
13	Business and Financial Operations Occupations	257
15	Computer and Mathematical Occupations	96
17	Architecture and Engineering Occupations	75
19	Life, Physical, and Social Science Occupations	24
21	Community and Social Service Occupations	55
23	Legal Occupations	29
25	Education, Training, and Library Occupations	175
27	Arts, Design, Entertainment, Sports, and Media Occupations	48
29	Healthcare Practitioners and Technical Occupations	203
31	Healthcare Support Occupations	131
33	Protective Service Occupations	62
35	Food Preparation and Serving Related Occupations	276
37	Building and Grounds Cleaning and Maintenance Occupations	135
39	Personal Care and Service Occupations	254
41	Sales and Related Occupations	246
43	Office and Administrative Support Occupations	656
45	Farming, Fishing, and Forestry Occupations	76
47	Construction and Extraction Occupations	1,940
49	Installation, Maintenance, and Repair Occupations	360
51	Production Occupations	149
53	Transportation and Material Moving Occupations	205
Total		**5,788**

Sources: E3, MDE, REMI, RESI, U.S. BLS

Office and Administrative Support Occupations have the second-highest growth at 656 positions annually, followed by Installation, Maintenance, and Repair Occupations with 360 jobs. An additional seven occupational groups are expected to experience growth of at least 200 positions annually through 2030.

The estimated employment effects by job zone under the Final GGRA Plan are shown in Figure 46. As illustrated below, the plurality of occupational growth occurs in in Job Zone 2 and represents nearly half of the jobs gained annually.

Figure 46: Employment Impacts by Job Zone for Final GGRA Plan

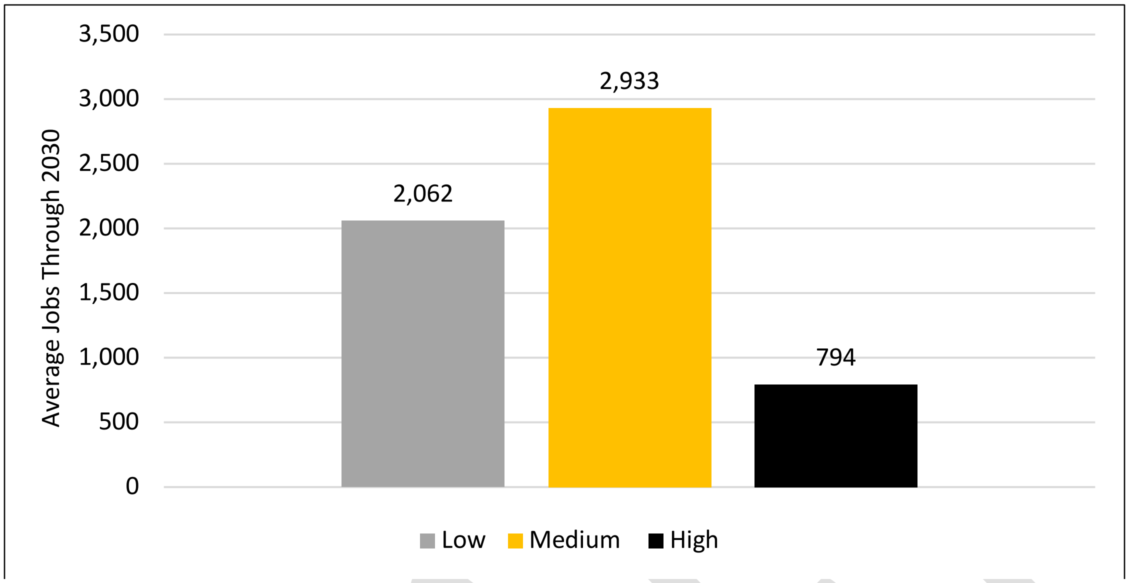


Sources: E3, MDE, O*Net, REMI, RESI

The distribution of employment by job zone in the Final GGRA Plan closely resembles that of the Draft GGRA Plan and MWG Scenario, with the most-substantial increases in jobs that typically require modest preparation and a high school diploma (Job Zone 2), followed by positions that generally require an associate degree or vocational training (Job Zone 3). This is beneficial in that retraining and educational needs are expected to be relatively less extensive and time consuming. No negative impacts are seen in any job zone under the Final GGRA Plan, with the smallest annual increases represented in Job Zone 5.

Employment distribution by wage groups for the Final GGRA Plan are shown in Figure 47 below.

Figure 47: Employment Impacts by Wage Group for Final GGRA Plan

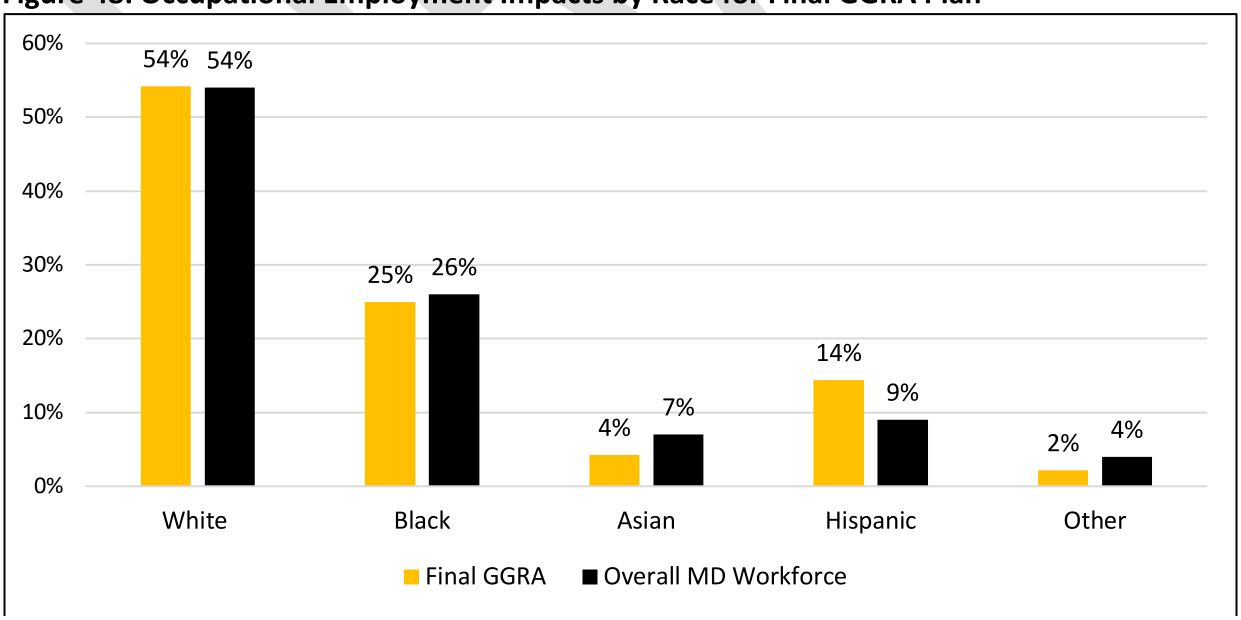


Sources: E3, MDE, REMI, RESI, U.S. BLS

Just over half of the employment impacts under the Final GGRA Plan (2,933 jobs) are found in medium-wage occupations earning between $35,000 and $65,000 annually. A higher number of positions are found in low-wage jobs than high-wage jobs, with more than twice the number of low-wage jobs than in the high-wage category.

Figure 48 shows how employment impacts in the Final GGRA Plan are distributed among racial groups, relative to the state's workforce as a whole.

Figure 48: Occupational Employment Impacts by Race for Final GGRA Plan

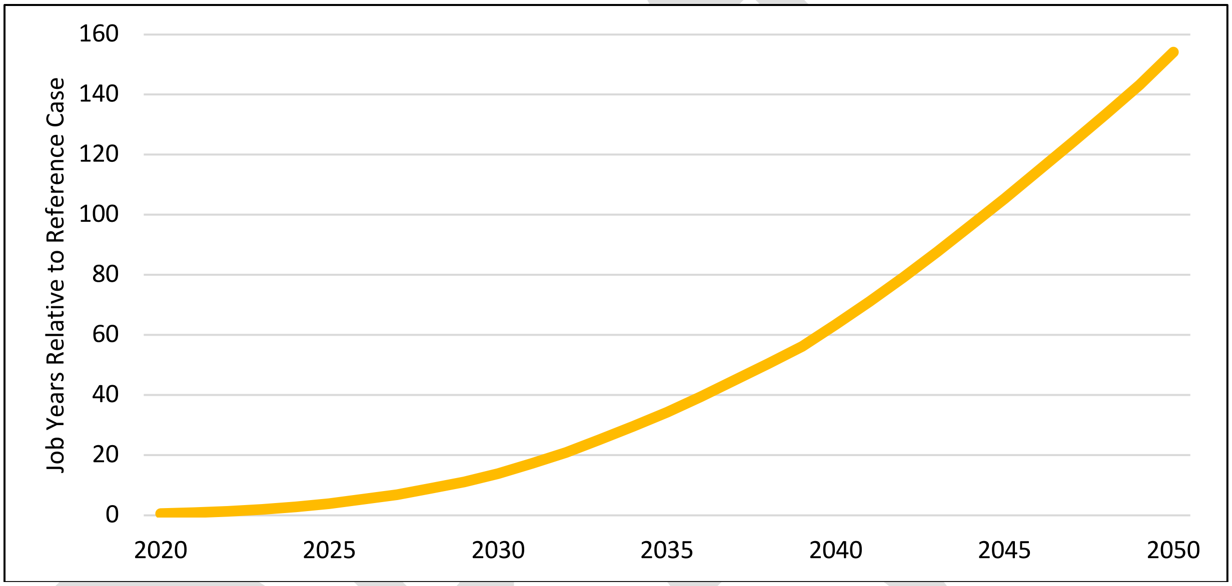


Sources: REMI, E3, MDE, MDOT, RESI, U.S. Census

As seen above, employment in the Final GGRA Plan is expected to track closely with the racial breakdown of Maryland's overall workforce, though there are some differences. Employment for Black and Asian workers is expected to be slightly underrepresented relative to the overall workforce, while Hispanic workers are forecasted to obtain a higher number of jobs relative to their overall representation.

Figure 49 shows the employment impacts that result specifically from improved health outcomes in the Final GGRA Plan.

Figure 49: Employment Impacts of Improved Health Outcomes for Final GGRA Plan



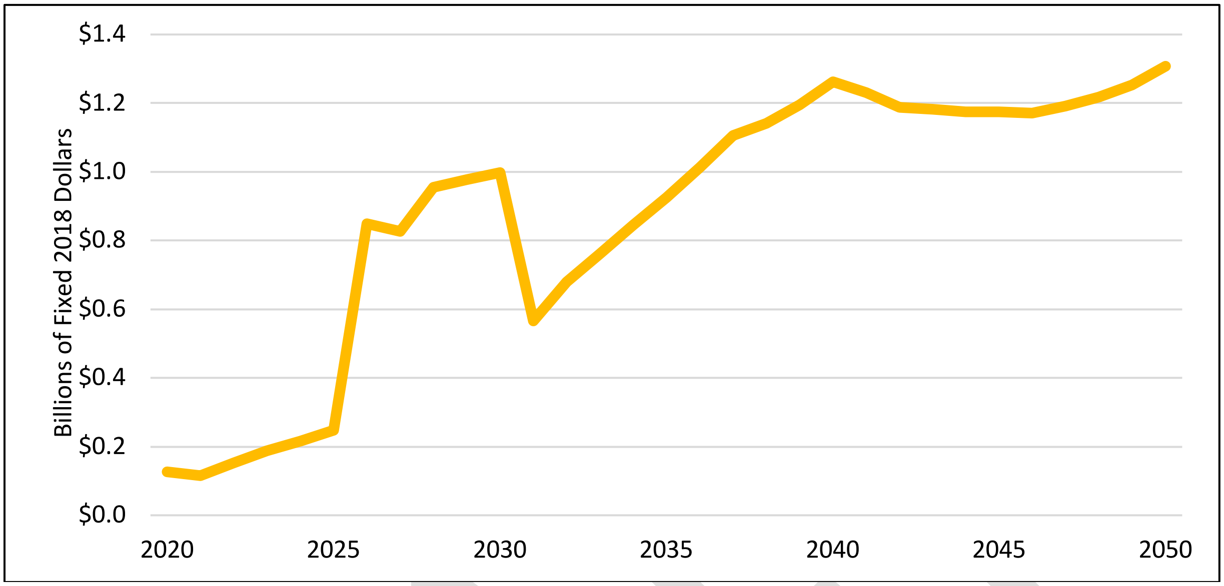
Sources: E3, MDE, MDOT, RESI, U.S. EPA

Between 2020 and 2030, improved health outcomes from the Final GGRA Plan will support an average of five jobs annually. This average increases to 50 jobs when extended to 2050. Detailed results for health impacts are found in Appendix C.5.

1.6.1.2 Personal Income in the Final GGRA Plan

As previously noted, personal income within REMI is calculated as the sum of total wages and salaries, supplements to these wages and salaries, property income, and personal current transfer receipts. Figure 50 below shows changes in personal income levels under the Final GGRA Plan, which remain positive through 2030.

Figure 50: Personal Income in the Final GGRA Plan Relative to the Reference Case



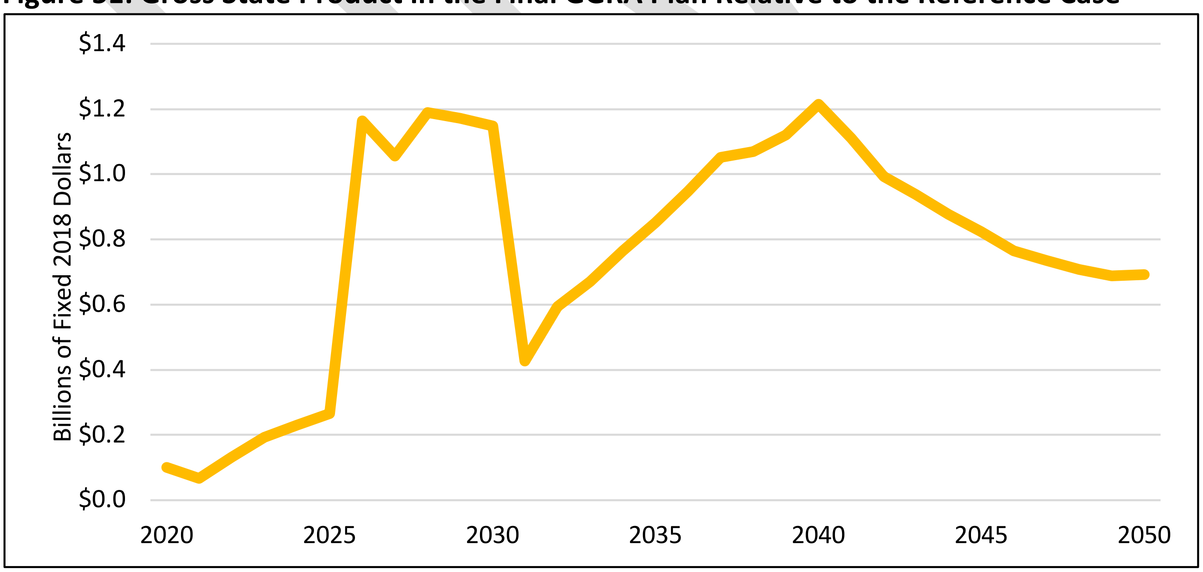
Sources: E3, MDE, REMI, RESI

Personal income is expected to rise under the Final GGRA Plan. Between 2020 and 2030, personal income exceeds the reference scenario by an average of $0.5 billion. A significant portion of this increase is due to spending on transportation infrastructure projects.

1.6.1.3 Gross State Product in the Final GGRA Plan

Gross state product (GSP) is the sum of consumption, investment, government spending, and net exports out of the state in a given year. Figure 51 shows the expected changes to Maryland's GSP under the Final GGRA Plan presented in billions of fixed 2018 dollars.

Figure 51: Gross State Product in the Final GGRA Plan Relative to the Reference Case



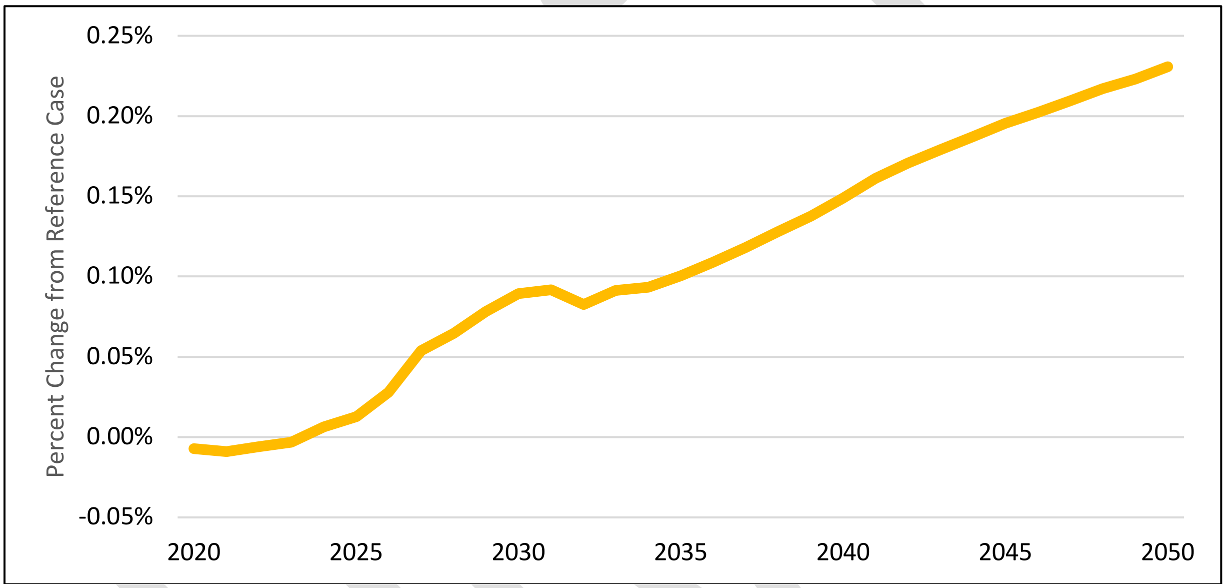
Sources: E3, MDE, REMI, RESI

Under the Final GGRA Plan, Maryland's GSP is forecasted to increase relative to the reference case in every year between 2020 and 2050. The change remains positive on average both with and without transportation infrastructure spending.

1.6.1.4 Consumer Prices in the Final GGRA Plan

Consumer prices are only expected to rise modestly under the Final GGRA Plan. As illustrated in Figure 52, on average, prices will rise 0.03 percent per year relative to the reference case between 2020 and 2030. Through 2050, prices will rise 0.11 percent relative to the reference case. This implies that a good or service that costs $1.00 in 2020 will cost less than one additional penny per year above inflation through both 2030 and 2050.

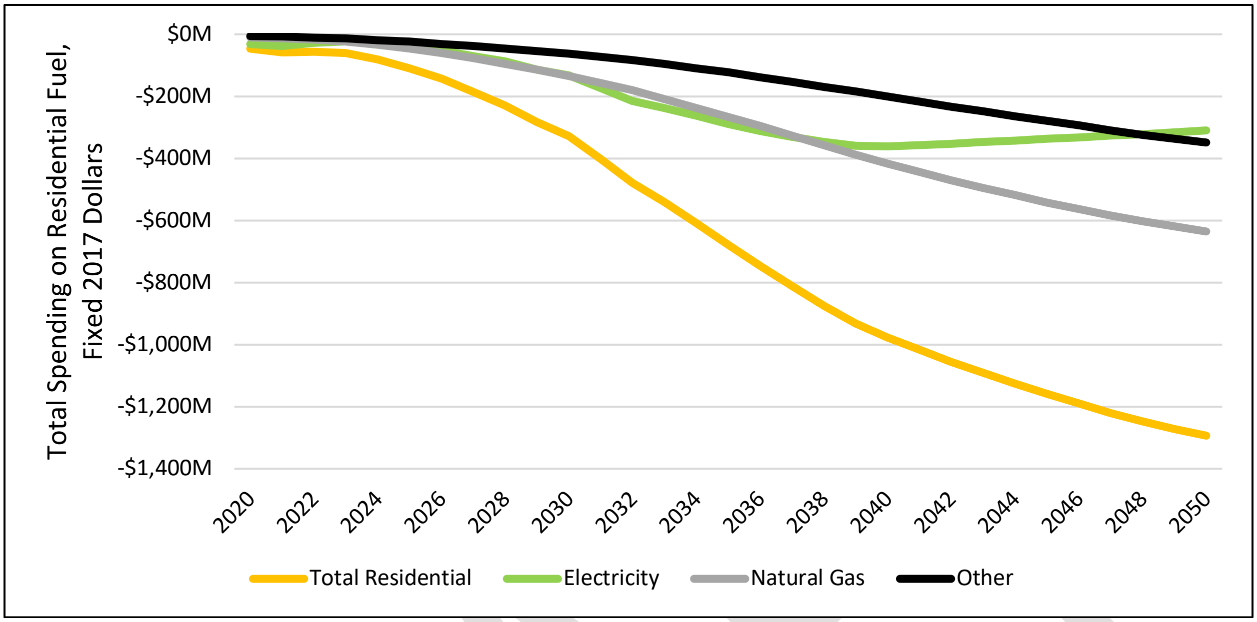
Figure 52: Percent Change in Consumer Prices in Final GGRA Plan Relative to the Reference Case



Sources: E3, MDE, REMI, RESI

When considering policies to reduce greenhouse gas emissions, one of the most relevant spending categories for consumers is utilities. Figure 53 shows residential non-transportation fuel spending in the Final GGRA Plan.

Figure 53: Total Residential Spending on Non-Transportation Fuel By Fuel Type in the Final GGRA Plan, Relative to the Reference Case



Sources: E3, MDE, RESI

As seen in Figure 53, total non-transportation fuel spending declines over time. This decline in spending in reflected across all types of residential fuel, including electricity and natural gas. Generally, electricity demand decreases for all sectors of the economy as consumers and businesses invest in more efficient appliances. The exception to this is the increase in electricity demand by the transportation sector, which reflects the transition from fossil fuels to electricity.

1.7 References

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Table 2-1. Key Assumptions in Baseline and Reference Scenario

	Baseline Scenario	**Reference Scenario (Existing Policies)**
Clean Electricity Standard	None	50% RPS by 2030 (Clean Energy Jobs Act)
RGGI	None	30% cap reduction from 2020 to 2030
Nuclear power	Assume Calvert Cliffs retires in 2034/2036 at end of license, and is replaced with electricity imports	Assume Calvert Cliffs is relicensed in 2034/2036 at end of license
Existing coal power plants	IPM planned retirements (670 MW of coal by 2023)	IPM planned retirements (670 MW of coal by 2023)
Rooftop PV	Current levels of 200 MW	Continued growth in deployment until net metering cap (1500 MW by 2026)
Energy Efficiency (Res., Com. & Industrial)	None	EmPOWER goals for 2015-2023, Calibrated to EmPOWER filing targets
Building Code	None	Continued building code improvement that leads to improved building shells in all new construction by 2030
Electrification of buildings (e.g. NG furnace to heat pumps)	None	None
Transportation	Federal CAFE standards for LDVs by 2026	Federal CAFE standards for LDVs by 2026; continued growth in ZEV LDVs driven by the ZEV Mandate
Other transportation sectors (e.g. aviation)	AEO 2017 reference scenario growth rates by fuel	AEO 2017 reference scenario growth rates by fuel
Industrial energy use	AEO 2017 reference scenario growth rates by fuel	AEO 2017 reference scenario growth rates by fuel
Biofuels	Existing ethanol and biodiesel blends, but no assumed increase	Existing ethanol and biodiesel blends, but no assumed increase
Other (fossil fuel industry, industrial processes, agriculture, waste management, forestry)	Assume held constant at MDE 2017 GHG Inventory levels	Small amount of forest management and healthy soils conservation practices

Each policy scenario was designed with a specific philosophy in mind. Detailed assumptions for each Scenario are detailed in Table 2-2. The MWG Scenario assumes more aggressive energy efficiency measures and building and light-duty vehicle electrifications. The 2030 GGRA Plan features more medium and heavy-duty vehicle electrifications and higher in-state clean energy resource requirement for electricity generation.

1. **MWG Scenario**: Policies and measures selected by the Mitigation Working Group (MWG) for consideration by the State
2. **2030 GGRA Plan**: MDE's plan to potentially achieve beyond the 2030 GHG target

Key Assumptions in Policy Scenarios from Documentation of Maryland PATHWAYS Scenario Modeling

	MWG Scenario	2030 GGRA Plan
Clean Electricity Standard	75% Clean energy by 2030, 100% by 2040	75% Clean and Energy Standard (CARES) by 2030, 100% by 2040; carveout for in-state clean energy resources reaching 10% by 2030 and 30% by 2040
RGGI	Accelerated RGGI cap that achieves 100% reductions by 2040	
Nuclear power	Assume Calvert Cliffs is relicensed in 2034/2036 at end of license	
Existing coal power	Chalk Point retired by 2022; all remaining in-state coal-fired power plants are ramped down and retired by 2030 as market forces cause coal retirements and Maryland complies with the increasingly stringent RGGI cap	
Rooftop PV	Increased net metering cap to 3 GW by 2030	
Energy Efficiency (Res., Com. & Industrial)	Additional EmPOWER achievements in efficiency as proxy for 3% annual savings goal (100% high efficiency electric sales by 2030, reduction in transmission and distribution losses from 5.4% to 4.6%)	Continued effort for efficiency in buildings (50% high efficiency electric sales by 2030, 25% for natural gas appliance sales); Renewed EmPOWER program pursing broader efficiency improvement (improved building shells for all new construction and 25% of retrofit buildings by 2030)
Electrification of buildings (e.g. NG furnace to heat pumps)	Aggressive building electrification (heat pump sales increase to 95% by 2050)	High levels of building electrification (heat pumps sales increase to 50% by 2030 and 80% by 2040) reflecting reformed EmPOWER program pursuing broader GHG and energy efficiency goals.
Fuel Economy Standards	Federal CAFE standards for LDVs through 2026	Extension of Federal CAFE standards for LDVs through 2030

Zero Emission Vehicles in Light Duty	Aggressive sales after 2025 (800,000 by 2030, 5 Million by 2050)	Increased sales after 2025, and aggressive sales after 2030 (790,000 by 2030, 4.5 Million by 2050) consistent with analysis performed for the Transportation and Climate Initiative (TCI).
Heavy Duty Vehicles	Aggressive sales of electric and diesel hybrid HDVs (40% sales by 2030 and 95% by 2050); truck stop electrification and zero-emission truck corridors	Aggressive sales of ZEV HDVs to meet the ZEV Truck Mandate (35% sales by 2030 and 100% by 2050); truck stop electrification and zero-emission truck corridors
Vehicle Miles Traveled	0.6% growth rate for LDV VMTs: Additional smart growth and transit measures	
Other transportation sectors (e.g. buses, construction vehicles)	Electrification of 50% of transit buses by 2030, 100% by 2050; Electrification of 50% of construction vehicles by 2040, 100% by 2050	Electrification of 75% of transit buses by 2030
Industrial energy use	30% reduction below Reference Scenario by 2050	
Biofuels	Existing ethanol and biodiesel blends	
Other (fossil fuel industry, industrial processes, agriculture, waste management, forestry)	More aggressive measures in enteric fermentation & manure management, forest management and healthy soils	Additional acreage in forest management and healthy soils conservation practices; reduced methane emissions from natural gas transmission and distribution.

Appendix A—Detailed Assumptions by Policy Scenario

This appendix contains information regarding how the policy scenarios were constructed as well as a comparison between the four scenarios.

Appendix B—Methodology

This appendix contains more information regarding the methodology that the Project Team utilized for the economic analysis. For more detail regarding the emissions modeling that was used as the basis of the economic analysis, please see Chapter 1.6.

B.1 REMI

To quantify the economic impacts of economic events or policy changes, RESI uses the Regional Economic Models, Inc. (REMI) model version 2.2. The REMI model is a high-end dynamic modeling tool used by various federal and state government agencies in economic policy analysis. Utilization of REMI helps RESI build a sophisticated model that is calibrated to the specific demographic features of the study area. This model enumerates the combined economic impacts of each dollar spent by the following: employees relating to the economic events, other supporting vendors (business services, retail, etc.), each dollar spent by these vendors on other firms, and each dollar spent by the households of the event's employees, other vendors' employees, and other businesses' employees. The REMI model reports economic impacts above the economic activity that would have occurred without the policy change or event.

As a dynamic model, REMI features the ability to capture price effects, wage changes, and behavioral effects through time. Another benefit of the model compared to traditional static models, such as IMPLAN, is that the regional constraint is built in, which accounts for limited resources over time. A situation like this is built into the model using current industry data and employment information from Bureau of Economic Analysis (BEA) data. The REMI model also allows RESI to capture the effects occurring between industries and minimize the potential for double-counting in employment, output, and wages. The ability to capture effects throughout a span of time provides a detailed representative of an economic event over time and its effects on the study area.

B.2 COBRA

The EPA's CO-Benefits Risk Assessment (COBRA) model assists state and local governments with estimating the costs and benefits of clean energy policies. Originally developed by Abt Associates in 2002, and most recently updated in 2017, COBRA "estimate[s] the economic value of the health benefits associated with clean energy policies and programs" so that these values can be weighed against the economic costs of a proposed policy.[37,38]

To use the COBRA model, a user first needs to estimate the reduction in emissions that would occur as a result of the clean energy policy. COBRA utilizes emission estimates for five different forms of air pollution: particulate matter ($PM_{2.5}$), sulfur dioxide (SO_2), nitrogen oxides (NO_X), ammonia (NH_3), and volatile organic compounds (VOCs).[39] Baseline emission estimates are included for both 2017 and 2025, allowing users to change emissions in either year.[40] Once the emission estimates for the policy are determined, the user can then input any corresponding emission increases or decreases from the baseline into the model. These changes can be input as either percentage changes from the baseline or as a specific quantity of emissions in tons.

Beyond year and pollutant type, emission changes can be further customized to specifically match the scenario being estimated through the model.[41] Changes can be entered at a national, state, or county level, including the 48 contiguous states and the District of Columbia. Changes can be further specified by the source of the emissions, with options such as highway vehicles or electric utility plants. COBRA allows the user to build a scenario with multiple changes across various locations and emissions, allowing a single scenario to contain variations in emission levels across different states or across different counties within the same state.

Regardless of the type(s) of air pollution input as changes into the model, COBRA will translate the changes in pollution into changes in ambient $PM_{2.5}$. In addition to changes to primary particles as a result of directly inputting changes in $PM_{2.5}$, changing one of the other emissions results in a change in secondary $PM_{2.5}$. Secondary $PM_{2.5}$ is formed by chemical reactions in the atmosphere involving other gaseous emissions.[42] For example, SO_2 will create sulfates in the atmosphere while NO_x will form nitrates, both of which are forms of $PM_{2.5}$.[43]

The changes in ambient $PM_{2.5}$ are then further translated into health impacts, which cover a wide range of effects from mortality and non-fatal heart attacks to work days missed and minor

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37 U.S. Environment Protection Agency, "User's Manual for the Co-Benefits Risk Assessment Health Impacts Screening and Mapping Tool (COBRA)," 3.

38 "CO-Benefits Risk Assessment (COBRA) Health Impacts Screening and Mapping Tool," U.S. Environment Protection Agency.

39 U.S. Environment Protection Agency, "User's Manual for the Co-Benefits Risk Assessment Health Impacts Screening and Mapping Tool (COBRA)," 18.

40 COBRA also contains the ability to import a custom emissions baseline for any other year, however this functionality was not used for this analysis.

41 U.S. Environment Protection Agency, "User's Manual for the Co-Benefits Risk Assessment Health Impacts Screening and Mapping Tool (COBRA)," 6-14.

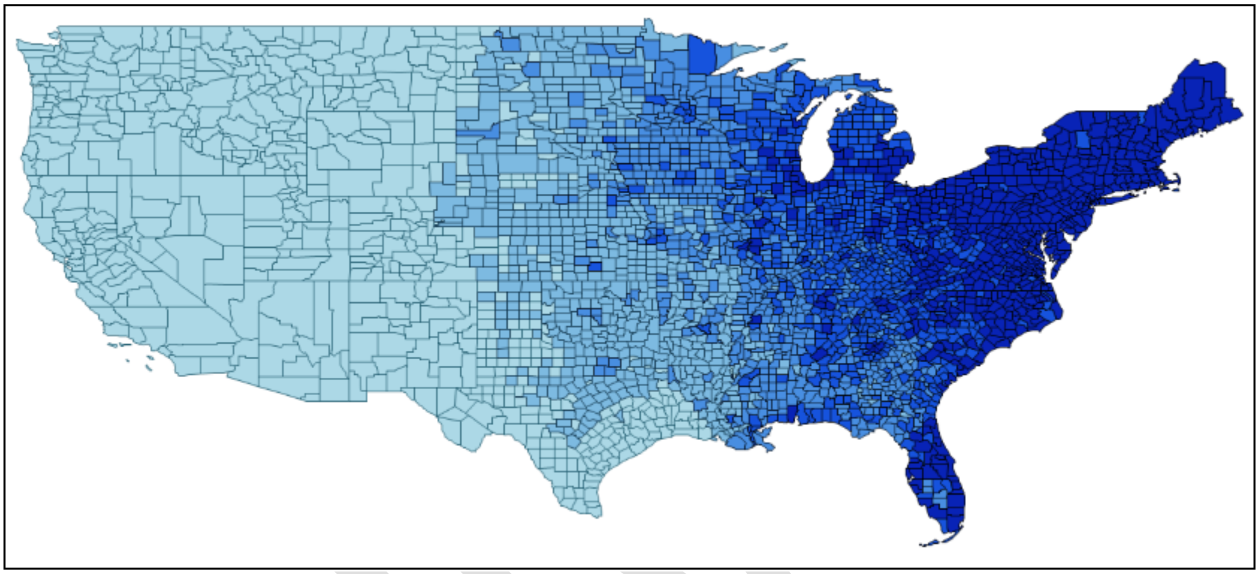
42 U.S. Environment Protection Agency, "Particulate Matter Emissions," accessed August 9, 2018, 1, https://cfpub.epa.gov/roe/indicator_pdf.cfm?i=19.

43 U.S. Environment Protection Agency, "Particulate Matter Emissions," 1.

restricted activity days (MRADs).[44] Finally, these various health impacts are assigned economic values in 2017 dollars.[45] Both a low and a high economic estimate are provided, based on "two sets of assumptions about the sensitivity of adult mortality and non-fatal heart attacks to changes in ambient $PM_{2.5}$."[46]

Although the most significant health impacts will be seen in the geographic location where the emissions were changed, COBRA provides the impact to air pollution levels within every county in the model, since air pollution is not subject to state and county lines. Figure 54 below is a map produced by COBRA illustrating total economic benefits for each county in the United States following a reduction in Maryland emissions. Generally, greater economic benefits are seen in counties closer to the reductions and in counties with higher populations.

Figure 54: Example of Emissions Result Map from COBRA



Source: U.S. EPA

COBRA is an industry and academically recognized tool for quantifying health impacts related to emissions. In 2016, a paper in the *International Journal of Environmental Research and Public Health* used COBRA to estimate the health and economic effects of Volkswagen's violations of the Clean Air Act. Volkswagen had installed software onto its diesel-fueled passenger cars that deactivated the NO_x emissions control system while driving but would reactivate the system

[44] U.S. Environment Protection Agency, "User's Manual for the Co-Benefits Risk Assessment Health Impacts Screening and Mapping Tool (COBRA)," 43-44.
[45] U.S. Environment Protection Agency, "User's Manual for the Co-Benefits Risk Assessment Health Impacts Screening and Mapping Tool (COBRA)," 7-8.
[46] U.S. Environment Protection Agency, "User's Manual for the Co-Benefits Risk Assessment Health Impacts Screening and Mapping Tool (COBRA)," 23.

whenever the car underwent emissions testing.[47] This illegal software caused each car to emit NO_x at a rate "10 to 40 times higher than the EPA's current Tier 2 vehicle emission standard."[48]

Using COBRA, the authors estimated that the additional NO_x from Volkswagen vehicles resulted in economic losses ranging from $43 million to $423 million related to premature deaths and other negative health impacts.[49,50] The wide range of the impact is a result of running multiple scenarios covering the range of increased emissions reported by the EPA, in addition to reporting both the high and low economic estimates from COBRA for each of these scenarios.

COBRA has also been previously used in studies specific to Maryland and the surrounding region. In 2016, the Chesapeake Climate Action Network used the tool to advocate for an increase in the renewable energy used by the District of Columbia. The organization estimated that the expansion of renewable energy could carry an economic benefit of up to $572 million annually from the resulting improvement in air quality.[51]

An extensive study was conducted by Abt Associates, the developers of COBRA, to examine the public health impacts and related economic benefits of the Regional Greenhouse Gas Initiative (RGGI) from 2009 to 2014. Using both COBRA and the more complex BenMAP tool, Abt Associates estimated that RGGI resulted in an economic benefit of $3.0 billion to $8.3 billion, stemming from the avoided negative health effects of air pollution over the six-year period.[52] Notably, Abt found significant health and economic benefits both in RGGI states and in neighboring states that did not participate in RGGI.[53]

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[47] Lifang Hou et al., "Public Health Impact and Economic Costs of Volkswagen's Lack of Compliance with the United States' Emission Standards," *International Journal of Environmental Research and Public Health* 13, no. 9 (2016): 1-2, accessed August 9, 2018, doi:10.3390/ijerph13090891.
[48] Hou et al., "Public Health Impact and Economic Costs of Volkswagen's Lack of Compliance with the United States' Emission Standards," 2.
[49] Hou et al., "Public Health Impact and Economic Costs of Volkswagen's Lack of Compliance with the United States' Emission Standards," 4.
[50] Values in this study are in 2010 dollars.
[51] Chesapeake Climate Action Network, "B21-0650—Renewable Portfolio Standard Expansion Amendment Act of 2016," 2, May 23, 2016, accessed August 9, 2018, http://chesapeakeclimate.org/wp/wp-content/uploads/2016/05/CCAN_B21-0650_testimony_DC-RPS.pdf.
[52] Abt Associates, "Analysis of the Public Health Impacts of the Regional Greenhouse Gas Initiative, 2009-2014," 2, January 2017, accessed August 9, 2018, https://www.abtassociates.com/sites/default/files/2018-06/Analysis%20of%20the%20public%20health%20impacts%20of%20regional%20greenhouse%20gas.pdf.
[53] Abt Associates, "Analysis of the Public Health Impacts of the Regional Greenhouse Gas Initiative, 2009-2014," 32

Appendix C—Detailed Results

C.1 Employment

Figure 55: Total Employment Impacts by Policy Scenario without Transportation Measures by Year Relative to the Reference Case, 2020-2050

Year	Draft GGRA	MWG	Final GGRA
Average through 2030	1,748	951	1,812
Average through 2050	3,085	-6,431	2,271
2020	810	1,921	1,322
2021	1,085	1,913	1,208
2022	1,380	1,887	1,399
2023	1,675	2,028	1,703
2024	1,723	1,787	1,906
2025	1,781	1,453	2,049
2026	1,828	993	2,039
2027	1,971	514	2,153
2028	2,136	-31	2,054
2029	2,365	-610	2,105
2030	2,470	-1,389	1,991
2031	2,146	-2,572	1,834
2032	1,847	-3,770	1,993
2033	1,643	-4,906	2,211
2034	1,552	-5,969	2,411
2035	1,532	-7,067	2,565
2036	1,648	-8,029	2,745
2037	1,882	-8,844	2,867
2038	2,166	-9,647	3,001
2039	2,566	-10,345	3,189
2040	3,139	-10,875	3,453
2041	3,585	-11,552	3,218
2042	4,027	-12,182	2,956
2043	4,455	-12,785	2,651
2044	4,895	-13,330	2,389
2045	5,339	-13,809	2,219
2046	5,750	-14,297	2,052
2047	6,254	-14,637	2,061
2048	6,797	-14,880	2,097
2049	7,318	-15,094	2,192
2050	7,872	-15,223	2,356

Sources: E3, MDE, REMI, RESI

Figure 56: Total Employment Impacts by Policy Scenario with Transportation Measures by Year Relative to the Reference Case, 2020-2050

Year	Draft GGRA	MWG	Final GGRA
Average through 2030	11,963	3,705	5,788
Average through 2050	6,655	-5,482	6,661
2020	11,949	4,526	1,816
2021	11,938	4,265	1,543
2022	11,947	4,143	1,842
2023	11,903	4,227	2,123
2024	11,618	3,959	2,317
2025	11,348	3,610	2,510
2026	12,707	4,747	10,724
2027	12,175	3,842	9,630
2028	11,990	3,158	10,674
2029	12,018	2,529	10,365
2030	12,004	1,750	10,130
2031	1,245	-3,127	4,685
2032	1,309	-3,817	5,827
2033	1,227	-4,770	6,455
2034	1,252	-5,791	7,022
2035	1,324	-6,921	7,502
2036	1,515	-7,945	8,022
2037	1,810	-8,827	8,526
2038	2,143	-9,687	8,438
2039	2,576	-10,425	8,479
2040	3,174	-10,980	8,511
2041	3,639	-11,666	7,980
2042	4,093	-12,295	7,403
2043	4,529	-12,888	7,194
2044	4,976	-13,419	6,974
2045	5,423	-13,882	6,811
2046	5,836	-14,352	6,632
2047	6,344	-14,676	6,597
2048	6,892	-14,906	6,565
2049	7,419	-15,109	6,563
2050	7,981	-15,228	6,646

Sources: E3, MDE, REMI, RESI

C.2 Gross State Product (GSP)

Figure 57: Gross State Product Impacts by Policy Scenario without Transportation Measures by Year Relative to the Reference Case, 2020-2050 (in Billions of 2018 Dollars)

Year	Draft GGRA	MWG	Final GGRA
Average through 2030	$0.24	$0.05	$0.15
Average through 2050	$0.57	-$1.11	$0.09
2020	$0.08	$0.18	$0.05
2021	$0.12	$0.18	$0.03
2022	$0.15	$0.18	$0.09
2023	$0.19	$0.20	$0.15
2024	$0.20	$0.16	$0.18
2025	$0.23	$0.12	$0.21
2026	$0.26	$0.06	$0.21
2027	$0.30	$0.00	$0.22
2028	$0.35	-$0.07	$0.19
2029	$0.40	-$0.15	$0.19
2030	$0.42	-$0.27	$0.15
2031	$0.40	-$0.43	$0.09
2032	$0.38	-$0.59	$0.10
2033	$0.37	-$0.75	$0.12
2034	$0.37	-$0.91	$0.15
2035	$0.38	-$1.09	$0.16
2036	$0.40	-$1.22	$0.18
2037	$0.44	-$1.34	$0.20
2038	$0.50	-$1.45	$0.22
2039	$0.57	-$1.55	$0.26
2040	$0.69	-$1.62	$0.36
2041	$0.75	-$1.78	$0.28
2042	$0.81	-$1.93	$0.19
2043	$0.88	-$2.07	$0.10
2044	$0.94	-$2.21	$0.00
2045	$1.01	-$2.35	-$0.08
2046	$1.08	-$2.50	-$0.16
2047	$1.16	-$2.63	-$0.20
2048	$1.24	-$2.75	-$0.24
2049	$1.32	-$2.88	-$0.26
2050	$1.40	-$2.99	-$0.26

Sources: E3, MDE, REMI, RESI

Figure 58: Gross State Product Impacts by Policy Scenario with Transportation Measures by Year Relative to the Reference Case, 2020-2050 (in Billions of 2018 Dollars)

Year	Draft GGRA	MWG	Final GGRA
Average through 2030	$1.18	$0.30	$0.61
Average through 2050	$0.88	-$1.03	$0.77
2020	$1.03	$0.39	$0.10
2021	$1.06	$0.37	$0.07
2022	$1.08	$0.37	$0.13
2023	$1.11	$0.38	$0.19
2024	$1.10	$0.35	$0.23
2025	$1.11	$0.31	$0.27
2026	$1.27	$0.40	$1.16
2027	$1.26	$0.30	$1.06
2028	$1.29	$0.23	$1.19
2029	$1.33	$0.14	$1.17
2030	$1.35	$0.03	$1.15
2031	$0.26	-$0.50	$0.43
2032	$0.29	-$0.60	$0.59
2033	$0.29	-$0.74	$0.67
2034	$0.30	-$0.90	$0.77
2035	$0.32	-$1.08	$0.85
2036	$0.36	-$1.22	$0.95
2037	$0.41	-$1.34	$1.05
2038	$0.47	-$1.46	$1.07
2039	$0.55	-$1.56	$1.12
2040	$0.67	-$1.64	$1.21
2041	$0.73	-$1.80	$1.11
2042	$0.80	-$1.95	$0.99
2043	$0.86	-$2.09	$0.94
2044	$0.93	-$2.23	$0.88
2045	$1.00	-$2.37	$0.82
2046	$1.07	-$2.51	$0.77
2047	$1.15	-$2.64	$0.74
2048	$1.24	-$2.76	$0.71
2049	$1.32	-$2.88	$0.69
2050	$1.40	-$3.00	$0.69

Sources: E3, MDE, REMI, RESI

C.3 Personal Income

Figure 59: Personal Income Impacts by Policy Scenario without Transportation Measures by Year Relative to the Reference Case, 2020-2050 (in Billions of 2018 Dollars)

Year	Draft GGRA	MWG	Final GGRA
Average through 2030	$0.16	-$0.08	$0.18
Average through 2050	$0.39	-$1.50	$0.35
2020	$0.05	$0.14	$0.09
2021	$0.08	$0.13	$0.09
2022	$0.10	$0.12	$0.12
2023	$0.13	$0.13	$0.15
2024	$0.14	$0.07	$0.18
2025	$0.16	$0.00	$0.20
2026	$0.17	-$0.09	$0.21
2027	$0.20	-$0.18	$0.23
2028	$0.22	-$0.28	$0.24
2029	$0.25	-$0.39	$0.25
2030	$0.27	-$0.53	$0.24
2031	$0.25	-$0.71	$0.23
2032	$0.23	-$0.89	$0.25
2033	$0.22	-$1.08	$0.28
2034	$0.21	-$1.26	$0.32
2035	$0.22	-$1.45	$0.35
2036	$0.23	-$1.63	$0.39
2037	$0.26	-$1.79	$0.42
2038	$0.29	-$1.96	$0.46
2039	$0.34	-$2.13	$0.52
2040	$0.41	-$2.26	$0.59
2041	$0.46	-$2.41	$0.58
2042	$0.52	-$2.56	$0.56
2043	$0.58	-$2.71	$0.53
2044	$0.64	-$2.85	$0.50
2045	$0.71	-$2.99	$0.48
2046	$0.77	-$3.13	$0.46
2047	$0.84	-$3.27	$0.47
2048	$0.92	-$3.39	$0.48
2049	$1.00	-$3.51	$0.52
2050	$1.08	-$3.63	$0.57

Sources: E3, MDE, REMI, RESI

Figure 60: Personal Income Impacts by Policy Scenario with Transportation Measures by Year Relative to the Reference Case, 2020-2050 (in Billions of 2018 Dollars)

Year	Draft GGRA	MWG	Final GGRA
Average through 2030	$1.04	$0.06	$0.51
Average through 2050	$0.73	-$1.46	$0.88
2020	$0.80	$0.28	$0.13
2021	$0.87	$0.25	$0.12
2022	$0.93	$0.24	$0.15
2023	$0.98	$0.24	$0.19
2024	$1.00	$0.19	$0.22
2025	$1.03	$0.12	$0.25
2026	$1.13	$0.12	$0.85
2027	$1.14	-$0.01	$0.83
2028	$1.16	-$0.12	$0.95
2029	$1.19	-$0.24	$0.98
2030	$1.22	-$0.37	$1.00
2031	$0.40	-$0.78	$0.57
2032	$0.36	-$0.91	$0.68
2033	$0.32	-$1.08	$0.76
2034	$0.29	-$1.26	$0.85
2035	$0.28	-$1.45	$0.92
2036	$0.29	-$1.63	$1.01
2037	$0.31	-$1.80	$1.11
2038	$0.34	-$1.98	$1.14
2039	$0.38	-$2.14	$1.20
2040	$0.45	-$2.28	$1.26
2041	$0.50	-$2.43	$1.23
2042	$0.55	-$2.58	$1.19
2043	$0.61	-$2.72	$1.18
2044	$0.67	-$2.87	$1.18
2045	$0.74	-$3.01	$1.17
2046	$0.80	-$3.15	$1.17
2047	$0.88	-$3.28	$1.19
2048	$0.96	-$3.40	$1.22
2049	$1.04	-$3.52	$1.25
2050	$1.12	-$3.63	$1.31

Sources: E3, MDE, REMI, RESI

C.4 Producer Consumption Expenditures (PCE)

Figure 61: PCE-Price Index (2009=100) Under Final GGRA Plan

Year	With Transportation Measures	Without Transportation Measures
Average through 2030	0.028	0.010
Average through 2050	0.109	0.069
2020	-0.007	-0.007
2021	-0.009	-0.010
2022	-0.006	-0.008
2023	-0.003	-0.005
2024	0.006	0.003
2025	0.013	0.010
2026	0.028	0.015
2027	0.054	0.019
2028	0.065	0.026
2029	0.078	0.029
2030	0.089	0.037
2031	0.092	0.039
2032	0.082	0.041
2033	0.092	0.044
2034	0.093	0.047
2035	0.101	0.053
2036	0.109	0.060
2037	0.118	0.066
2038	0.128	0.074
2039	0.138	0.083
2040	0.149	0.094
2041	0.161	0.107
2042	0.171	0.116
2043	0.179	0.125
2044	0.187	0.133
2045	0.195	0.140
2046	0.202	0.147
2047	0.210	0.154
2048	0.217	0.161
2049	0.223	0.166
2050	0.231	0.174

Sources: E3, MDE, REMI, RESI

C.5 Health Impacts

Figure 62: Jobs Due to Health Impacts by Policy Scenario

Year	Draft GGRA	MWG	Final GGRA
Average Through 2030	4.75	4.49	5.24
Average Through 2050	29.36	44.38	49.97
2020	0.73	0.06	0.58
2021	1.21	0.39	0.85
2022	1.76	0.89	1.33
2023	2.38	1.55	1.98
2024	3.07	2.35	2.79
2025	3.96	3.43	3.93
2026	4.97	4.67	5.29
2027	6.17	6.14	6.93
2028	7.61	7.88	8.91
2029	9.22	9.83	11.15
2030	11.14	12.23	13.96
2031	13.27	15.03	17.23
2032	15.55	18.20	20.93
2033	18.01	21.80	25.10
2034	20.54	25.71	29.59
2035	23.16	29.91	34.38
2036	25.88	34.43	39.50
2037	28.66	39.17	44.86
2038	31.53	44.16	50.47
2039	34.44	49.36	56.31
2040	37.82	55.73	63.42
2041	41.39	62.60	71.04
2042	45.17	69.90	79.13
2043	49.21	77.71	87.75
2044	53.42	85.72	96.50
2045	57.84	93.99	105.47
2046	62.46	102.51	114.67
2047	67.25	111.27	124.07
2048	72.15	120.16	133.56
2049	77.19	129.25	143.21
2050	82.94	139.64	154.17

Sources: E3, MDE, MDOT, RESI, U.S. EPA

Figure 63: Avoided Mortality and Estimated Value by Policy Scenario

Year	Draft GGRA		MWG		Final GGRA	
	Mortality Avoided	Value	Mortality Avoided	Value	Mortality Avoided	Value
Average Through 2030	7.83	$77,921,556	10.25	$101,965,805	17.37	$172,795,656
Average Through 2050	28.03	$278,903,141	46.80	$465,640,433	72.75	$723,768,906
2020	2.34	$23,303,269	4.02	$40,006,798	3.61	$35,899,882
2021	3.15	$31,292,510	4.98	$49,576,950	5.48	$54,554,047
2022	3.88	$38,639,638	5.75	$57,189,878	7.36	$73,208,211
2023	4.64	$46,124,924	6.53	$64,939,152	9.23	$91,862,375
2024	5.40	$53,748,367	7.32	$72,824,772	11.11	$110,516,540
2025	6.82	$67,849,226	9.12	$90,729,028	15.52	$154,425,034
2026	8.30	$82,565,903	10.80	$107,466,202	19.25	$191,496,640
2027	9.97	$99,160,555	12.68	$126,198,572	22.97	$228,568,246
2028	11.82	$117,633,182	14.77	$146,926,139	26.70	$265,639,852
2029	13.63	$135,624,171	16.68	$165,970,494	30.43	$302,711,458
2030	16.20	$161,195,366	20.08	$199,795,875	39.39	$391,869,935
2031	18.27	$181,731,324	23.42	$232,968,210	44.73	$444,977,852
2032	20.32	$202,121,837	27.10	$269,574,917	50.06	$498,085,770
2033	22.35	$222,366,906	31.12	$309,615,998	55.40	$551,193,687
2034	24.10	$239,765,512	34.95	$347,714,180	60.74	$604,301,605
2035	25.88	$257,437,810	38.85	$386,477,625	66.08	$657,409,522
2036	27.68	$275,383,800	42.81	$425,906,333	71.42	$710,517,439
2037	29.51	$293,603,482	46.84	$466,000,304	76.75	$763,625,357
2038	31.37	$312,096,855	50.94	$506,759,539	82.09	$816,733,274
2039	33.26	$330,863,920	55.10	$548,184,037	87.43	$869,841,191
2040	36.58	$363,911,152	63.85	$635,210,429	107.68	$1,071,278,223
2041	39.27	$390,666,003	69.79	$694,367,280	112.59	$1,120,108,794
2042	42.05	$418,363,035	75.71	$753,221,990	117.49	$1,168,939,366

Year	Draft GGRA		MWG		Final GGRA	
	Mortality Avoided	Value	Mortality Avoided	Value	Mortality Avoided	Value
2043	44.93	$447,002,247	81.59	$811,774,559	122.40	$1,217,769,937
2044	47.38	$471,370,118	85.77	$853,298,575	127.31	$1,266,600,508
2045	49.86	$496,082,985	90.00	$895,384,663	132.22	$1,315,431,080
2046	52.38	$521,140,850	94.28	$938,032,826	137.13	$1,364,261,651
2047	54.93	$546,543,712	98.63	$981,243,062	142.03	$1,413,092,222
2048	57.52	$572,291,572	103.03	$1,025,015,371	146.94	$1,461,922,793
2049	60.15	$598,384,428	107.48	$1,069,349,754	151.85	$1,510,753,365
2050	65.11	$647,732,708	116.91	$1,163,129,919	171.80	$1,709,240,224

Sources: E3, MDE, RESI, U.S. EPA

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