Maryland
Department of
the Environment

Supplemental Information

Emissions Sensitivity Analysis

2030 GGRA Plan

Energy+Environmental Economics
101 Montgomery Street | Suite 1600 | San Francisco, CA 94104 | 415.391.5100 | www.ethree.com

Documentation of Maryland PATHWAYS Scenario Modeling Addendum Report

December 16, 2021

Prepared for the Maryland Department of Environment

On behalf of the Regional Economic Studies Institute at Towson University

By Energy and Environmental Economics, Inc.

Charles Li

Tory Clark

Snuller Price

Contents

1 Report Background

Energy + Environmental Economics (E3) has been supporting the Maryland Department of the Environment (MDE) in developing energy and emissions scenarios to chart a path towards decarbonization in the State. These scenarios then feed into a macroeconomic assessment of Maryland's greenhouse gas (GHG) reduction policies conducted by the Regional Economic Studies Institute (RESI) at Towson University. This analysis was divided into three phases;

- The first phase (2017) included the development of a reference case of GHG emissions for Maryland consistent with existing energy policies in the LEAP model. This work was presented to the Mitigation Working Group of the Maryland Commission on Climate Change in February, 2018.
- The second phase (2018-2019) included an evaluation of deeper GHG reduction scenarios with additional measures. A draft Greenhouse Gas Emissions Reduction Act (GGRA) plan was released in October, 2019 by MDE to achieve Maryland's goal of reducing greenhouse gas (GHG) emissions by 40% by 2030.
- The third phase (2020-2021) includes an update of the reference case developed in the first phase and an evaluation of two additional GHG reduction scenarios with more aggressive measures. Analysis in this phase led to the release of the 2030 GGRA Plan.

Following the release of the 2030 GGRA Plan, MDE further designed seven additional scenarios as sensitivities:

- Two sensitivities reflecting different levels of potential federal actions
- Five in-and-out scenarios for evaluating the impact of key state policies and measures that will help Maryland achieve the near-term GHG reduction goal the Plan

This report provides documentation for E3's modeling of Maryland's GHG emissions projection under the seven scenarios using the PATHWAYS model, focusing on key assumptions and GHG emissions results.

In addition, this report also documents two amendments to the 2030 GGRA Plan Document

- Updated GHG emissions reflecting revised historical landfill emissions estimates by MDE, and an adjustment to projected electricity generation in later years
- Revision of annual electricity emissions charts (Figures 3-12 and 3-13) in Appendix F of the 2030 GGRA Plan Document

2 Revision to GHG Emissions from Landfills

2.1 Updated Landfills GHG Emissions

MDE revised the estimate of GHG emissions from landfills, which is part of the non-combustion emissoins in the Waste Management sector. The revision applies to both 2006 and 2017 landfills emissions compared to previously released Maryland Geenhouse Gas Inventories. Table 2-1 shows landfills emissions in the previously released GGRA Plan Document and the updated estimates.

Table 2-1. Historical Greenhouse Gas Emissions from Landfills in Maryland

Landfills Emissions [MMT CO2e]	2006	2017
Previously Released Maryland Greenhouse Gas Inventories	0.47	0.57
Updated Estimates	2.69	2.07

2.2 Updated Electricity GHG Emissions

A discrepancy was found in the electricity generation projections in the previously released results. The total electricity generation in the MWG Scenario and the 2030 GGRA Plan were not enough to meet the projected electric load. The discrepancy only affects electricity generation and the associated emissions after 2037, and therefore 2030 projections for the 2030 GGRA Plan are not affected. An adjustment was made to close the gap by ramping up imports and utility solar based on the generation mix of the two resources in each model year. Table 2-2 shows the comparison of the previously released electric-sector GHG emissions and the updated values. The adjustment leads to an increase of 0.45 MMT CO2e in electric-sector emissions in 2050 in the 2030 GGRA Plan scenario, only ~1% increase to 2050 statewide gross emissions.

Table 2-2. Total Electric-sector GHG Emissions by Policy Scenario, Previously Releases vs. Updated Results

[MMT CO2e]	2030		2050	
	Previous	Updated	Previous	Updated
MWG Scenario	9.63	9.63	4.48	5.24
2030 GGRA Plan	8.80	8.80	3.23	3.68

2.3 Updated Net GHG Emissions

Table 2-3 shows updated GHG emissions projections from selected years, and the updated GHG goals due to the change of 2006 baseline emissions. Net emissions in all scenarios increase compared to the previously released results, due to the revised landfills emissions (impacting results in all years) and the revised electricity GHG emissions (only impacting results after 2037). Landfills emissions In all scenarios are assumed unchanged after 2017.

Table 2-3. Total Net GHG Emissions by Policy Scenario (revision to Tables 1-1 and 3-1 in Appendix F of the 2030 GGRA Plan Document)

[MMT CO2e]	2020	2030	2040	2050
Reference	65.7	58.7	60.4	65.2
MWG Scenario	65.7	45.1	29.0	20.7
2030 GGRA Plan	65.7	45.1	28.2	20.4
GHG Goals	70.9	54.4	32.3	10.3

3 Revision of annual electricity emissions charts

Figure 3-1 and Figure 3-2 show updated annual electricity emissions results by resource type for all scenarios, in revision to Figures 3-12 and 3-13 in Appendix F of the 2030 GGRA Plan Document. The previous charts overstated the emissions from natural-gas-fired electricity generation. Figure 3-2 now correctly shows that all in-state gas generation become zero starting in 2040 in both the MWG scenario and the 2030 GGRA Plan.

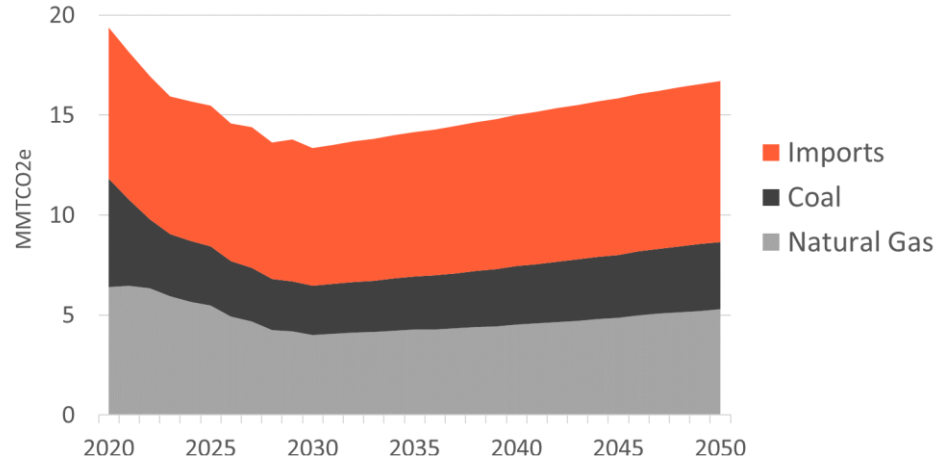

Figure 3-1. Annual Electricity Emissions by Resource Type, Reference Scenario (Revision to Figures 3-12 in Appendix F of the 2030 GGRA Plan Document)

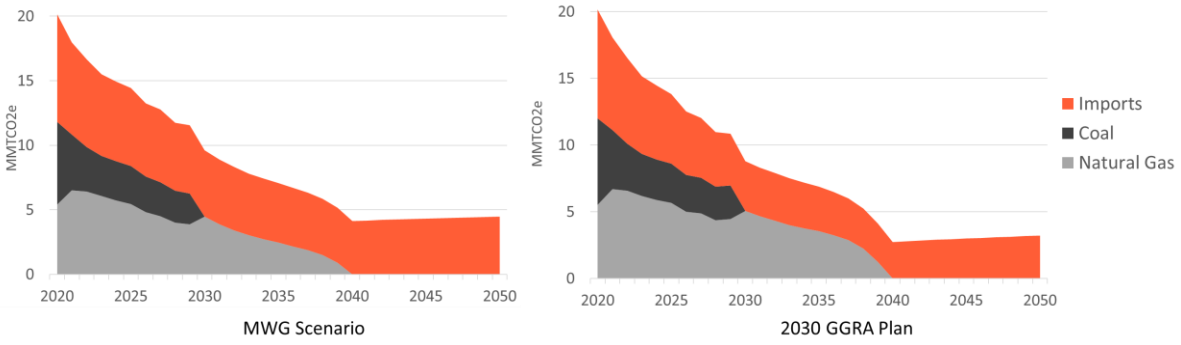

Figure 3-2. Annual Electricity Emissions by Resource Type and Policy Scenario (Revision to Figures 3-13 in Appendix F of the 2030 GGRA Plan Document)

4 Sensitivity Scenario Results

Figure 4-1 shows the results of two sensitivities on the 2030 GGRA Plan, designed to evaluate the impact of different levels of federal policies. The Optimistic Sensitivity reflects additional federal investment in green buildings, electric vehicles, low-carbon electricity, biofuels, and agricultural management practices. It has a small impact in 2030, but a significant impact by 2050 with 30 years of compounded adoption of electric heat pumps, electric vehicles, and efficient appliances. The Optimistic scenario achieves 54% reduction below 2006 GHG emissions by 2030 and 84% by 2050 on a gross emissions basis. The Pessimistic Sensitivity reflects lack of federal actions that result in slower pace of electrification and efficiency improvement, as well as early retirement of Calvert Cliffs nuclear power plant in 2023. It has an immediate impact in 2030 due to the replacement of Calvert Cliffs by carbon-emitting imports from PJM. The Pessimistic Sensitivity achieves 41% reduction by 2030 on a gross emissions basis.

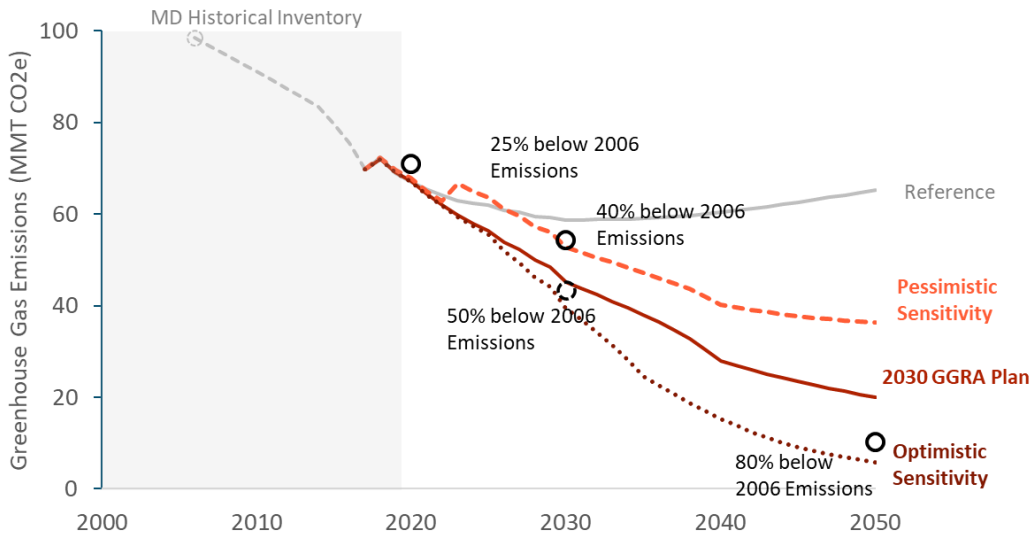

Figure 4-1. Maryland Net GHG Emissions for Sensitivities on the 2030 GGRA Plan, 2020-2050

Table 4-1 Maryland Net GHG Emissions of 2030 GGRA Plan Sensitivities

[MMT CO2e]	2020	2030	2040	2050
2030 GGRA Plan	65.7	45.1	27.9	19.9
Optimistic Sensitivity	65.7	39.4	15.3	5.9
Pessimistic Sensitivity	65.7	52.8	40.1	36.3
GHG Goals	70.9	54.4	32.3	10.3

Figure 4-2 shows that, in the near term, lower GHG emissions in the Optimistic Sensitivity than in the 2030 GGRA plan is mainly attributed to lower-carbon electricity generation to achieve nationwide carbon-free electricity by 2035. Figure 4-3 shows that, in the long term, aggressive electrification and efficiency measures, together with the blend of low-carbon advanced biofuels with fossil fuels, further lower GHG emissions in the Optimistic Sensitivity.

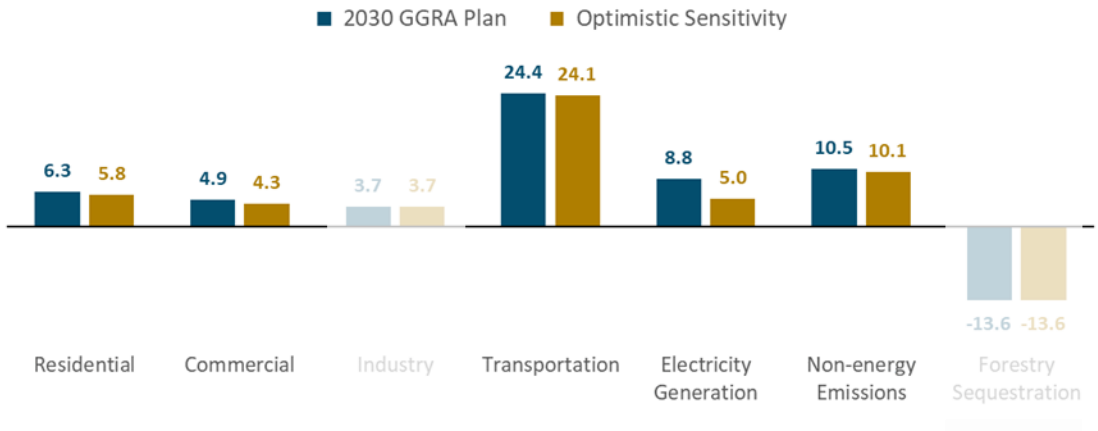

Figure 4-2. 2030 GHG Emissions for the 2030 GGRA Plan and Optimistic Sensitivity by Sector

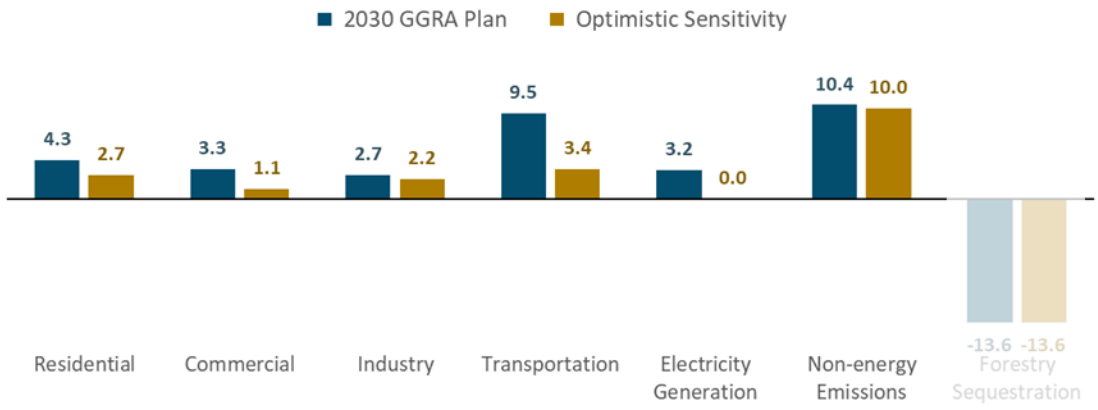

Figure 4-3. 2050 GHG Emissions for the 2030 GGRA Plan and Optimistic Sensitivity by Sector

Figure 4-4 shows that, in the near term, higher GHG emissions in the Pessimistic Sensitivity compared to 2030 GGRA plan is mainly attributed to the early retirement of Calvert Cliffs by 2023 and reduced vehicle efficiency improvement. Figure 4-5 shows that, in the long term, significantly reduced levels of building electrification, efficiency improvement and zero-emission vehicle adoption further increase GHG emissions in the Pessimistic Sensitivity

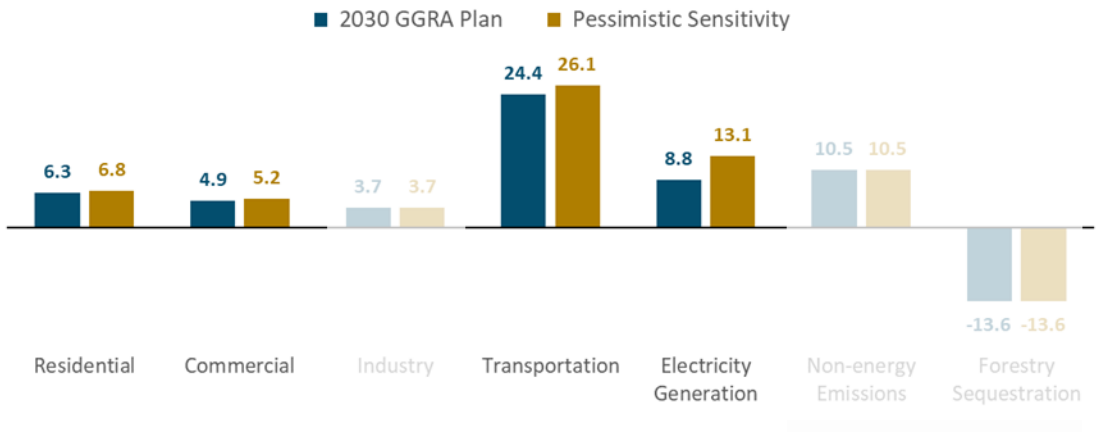

Figure 4-4. 2030 GHG Emissions for the 2030 GGRA Plan and Pessimistic Sensitivity by Sector

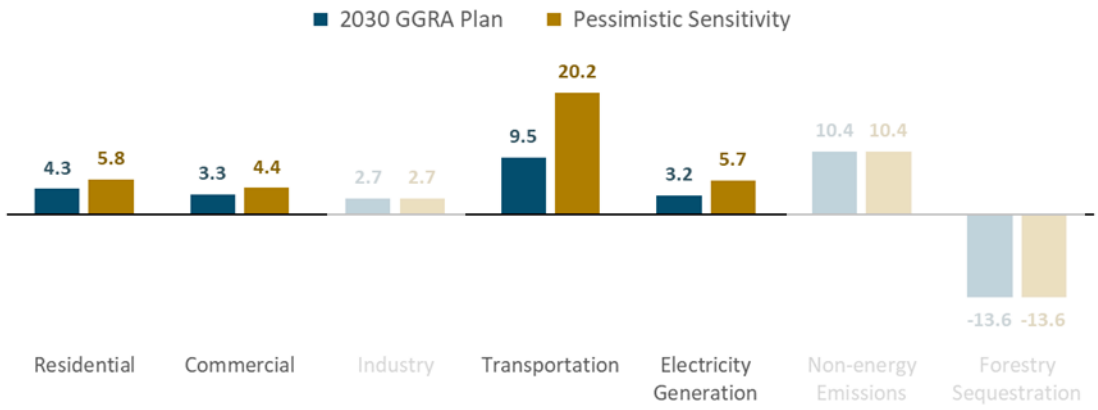

Figure 4-5. 2050 GHG Emissions for the 2030 GGRA Plan and Pessimistic Sensitivity by Sector

The results of the sensitivities highlight that

- Additional federal investment in electrification, nationwide clean electricity and sustainable low-carbon fuels can help Maryland achieve deeper GHG emission reductions both in the near term (beyond 50% by 2030) and in the long term (beyond 80% by 2050)
- Maryland may still achieve the 2030 GGRA target even with the retirement of Calvert Cliffs; however reduced level of electrification and efficiency improvement due to lack of federal action may keep the state from achieving any long-term GHG reduction goals commensurate to what other states are committed to

5 In-and-Out Scenario Results

The five in-and-out scenarios are designed to evaluate the impact of state policies and measures from key sectors:

- **No TCI scenario** models what if the Transportation and Climate Initiative (TCI) proceeds are not available to increase electric vehicle sales and reduce vehicle miles traveled or vehicle fuel consumptions
- **No EMPOWER scenario** models what if the EMPOWER building efficiency program is discontinued after 2023 and there are no other energy efficiency measures for buildings and industry from the 2030 GGRA Plan
- **No Building Decarbonization scenario** models what if levels of building electrification and building shell improvement revert to Reference levels
- **No MHDV Electrification scenario** models what if there is no electrification of medium-and-heavy-duty vehicles
- **No CARES scenario** models what if CARES does not take effect, and therefore in-state generation only meets the 50% RPS target by 2030. To isolate the impact of CARES, other RGGI states held at zero-carbon target by 2040, as in the 2030 GGRA Plan
    - **Reference RGGI scenario** is modeled as an extra scenario to evaluate the impact of actions from other RGGI states. This scenario models what if CARES does not take effect and GHG cap of other RGGI states achieves only 30% reduction by 2030 relative to 2020 from the Reference scenario

Figure 5-1 shows the results of all in-and-out scenarios:

- **No TCI scenario** shows that, without investments of TCI proceeds, more vehicle miles traveled, higher vehicle fuel consumption and fewer electric light-duty vehicles all increase GHG emissions, especially in the long term
- **No EMPOWER scenario** shows that, end of the EMPOWER building efficiency program and absence of other energy efficiency measures for buildings and industry result in lower adoption of efficient appliances, smart devices and behavioral conservation, and increases GHG emissions over time
- **No Building Decarbonization scenario** shows that, lower levels of building electrification and building shell improvement result in increased fossil fuel consumptions and GHG emissions over time from Maryland buildings
- **No MHDV Electrification scenario** shows that, without electrification of medium-and-heavy-duty vehicles, Maryland would have higher consumption of fossil fuels, mainly diesel, which increases GHG emissions, especially in the long term
- **No CARES and Reference RGGI scenarios** show that CARES has much larger GHG impact than RGGI cap in 2050, because CARES achieves higher levels of GHG reductions in the long term for in-state generation than the 50% RPS target

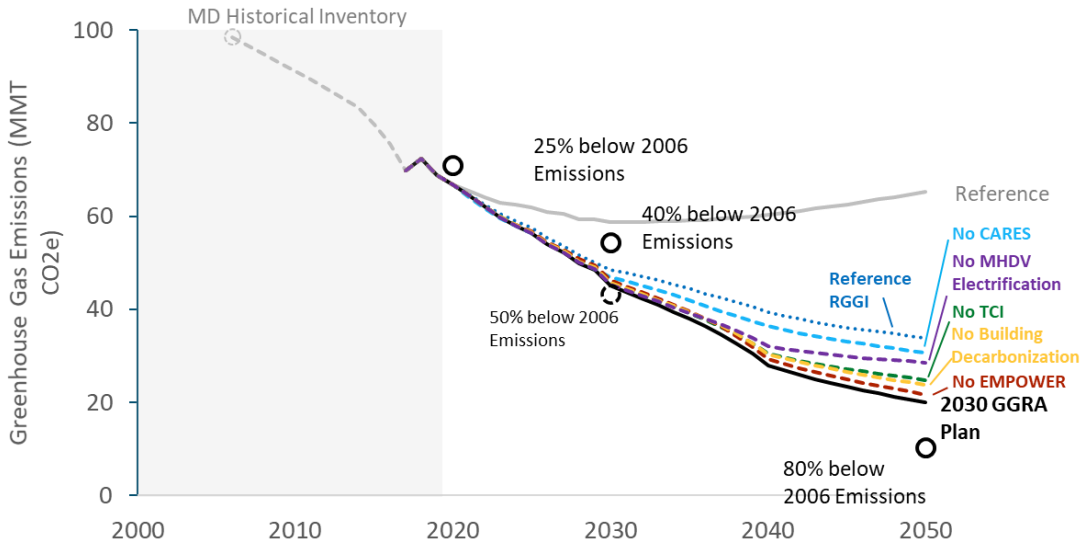

Figure 5-1. Maryland Net GHG Emissions for 2030 GGRA Plan In-and-Out Scenarios, 2020-2050. Each line represents the independent impact of an individual scenario where certain policies and measures are removed from the 2030 GGRA Plan. These are NOT showing a stacked effect of incremental changes in policies or measures.

Table 5-1. Maryland Net GHG Emissions of 2030 GGRA Plan In-and-Out Scenarios

[MMT CO2e]	2020	2030	2040	2050
2030 GGRA Plan	65.7	45.1	27.9	19.9
No TCI	65.7	45.7	30.5	24.9
No EMPOWER	65.7	46.2	29.3	21.7
No Building Decarbonization	65.7	45.7	30.3	23.7
No MHDV Electrification	65.7	45.4	32.1	28.6
No CARES	65.7	46.9	36.4	30.7
Reference RGGI	65.7	48.5	39.5	33.9
GHG Goals	70.9	54.4	32.3	10.3

Results of the in-and-out analysis highlight that

- In the near term, the five measures evaluated, including TCI, EMPOWER and other efficiency measures, building decarbonization, MHDV electrification and CARES, are a critical combination as Maryland pursues 50% GHG reduction by 2030 under the 2030 GGRA Plan
- In the long term, as shown in the published 2030 GGRA Plan, Maryland needs more than these five measures to achieve 80% reductions by 2050, or beyond

6 Appendix

Table 6-1. Policies and measures in the 2030 GGRA Plan, and the Optimistic and Pessimistic Sensitivities

	2030 GGRA Plan	Optimistic Sensitivity	Pessimistic Sensitivity
Clean Electricity Standard	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	Nationwide 100% carbon-free electricity by 2035 (Biden's proposed infrastructure plan)	Same as 2030 GGRA Plan
Nuclear power	Assume Calvert Cliffs is relicensed in 2034/2036 at end of license		Calvert Cliffs Retirement in 2023 with imports filling the gap
Energy Efficiency	Continued EmPOWER for efficiency in buildings *(50% high efficiency electric sales by 2030, 25% for natural gas appliance sales)*	Additional EmPOWER achievements in efficiency reflecting federal investment in building retrofits for pursuing broader energy efficiency goals *(100% high efficiency electric sales by 2030)*	Half of efficiency achieved in 2030 GGRA Plan
Building Code	Improved building shells for all new construction and 25% of retrofit buildings by 2030	Improved building shells for all new construction and 50% of retrofit buildings by 2030 reflecting federal investment in green buildings	Same as 2030 GGRA Plan
Electrification of buildings	High levels of building electrification reflecting reformed EmPOWER program *(heat pumps*	Achieving same levels of building electrification in 2030 GGRA Plan 5 years earlier reflecting federal investment in building	Half of electrification levels achieved in 2030 GGRA Plan

	sales increase to 50% by 2030 and 80% by 2040)	retrofits *(heat pumps sales increase to 50% by 2025 and 80% by 2035)*	
Fuel Economy Standards	Extension of Federal CAFE standards for LDVs through 2030	Same as 2030 GGRA Plan	Federal SAFE standards reflecting reduced vehicle efficiency improvement until 2025 and flat thereafter
Zero Emission Vehicles	Increased sales of ZEV LDVs after 2025 and aggressive sales after 2030; aggressive sales of ZEV MHDVs to meet the ZEV Truck Mandate	100% ZEV LDV sales by 2035, and 100% ZEV MHDV sales by 2045, reflecting federal investment in electric vehicles	Half of LDV and MHDV electrification levels achieved in 2030 GGRA Plan
Biofuels	Existing ethanol and biodiesel blends, but no assumed increase	Advanced sustainable biofuels blended into diesel and natural gas reflecting federal investment in bioenergy development	Same as 2030 GGRA Plan
Other (fossil fuel industry, industrial processes, agriculture, etc.)	Forest management and healthy soils conservation practices; reduced methane emissions from natural gas transmission and distribution.	More aggressive measures in enteric fermentation & manure management reflecting federal incentives for improving agricultural management practices; 10% of cement industrial emissions are reduced through carbon capture and storage by 2030 reflecting federal incentives for carbon removal technologies	Same as 2030 GGRA Plan

Table 6-2. Policies and measures where 2030 GGRA Plan and No TCI scenario are different

	2030 GGRA Plan	No TCI Scenario
Zero Emission Vehicles	65% new sales of ZEVs (electric vehicle and plug-in hybrid) in light duty autos (LDAs) and 25% in light duty trucks (LDTs) by 2030 and 100% by 2050 assuming aggressive ZEV adoption	Continued growth in ZEV LDVs driven by the ZEV Mandate (42% ZEV light duty auto (LDA) sales by 2030, and 8% ZEV light duty truck (LDT) sales by 2030), same as Reference assumptions
Vehicle Miles Traveled	Maryland Department of Transportation (MDOT) emerging and innovative strategies for highway management, smart transit, etc.	Without TCI proceeds, effect of MDOT measures are reduced by 9% (share of TCI proceeds in total state investment for MDOT measures)

Table 6-3. Policies and measures where 2030 GGRA Plan and No EMPOWER scenario are different

	2030 GGRA Plan	No EMPOWER Scenario
Energy Efficiency	Continued effort for efficiency in buildings; Renewed EmPOWER program pursing broader efficiency improvement	EmPOWER goals for 2015-2023, Calibrated to EmPOWER filing targets, same as Reference assumptions
Efficient building appliance sales	50% of new sales of all electric appliances are assumed to be efficient (e.g. EnergyStar) from 2015-2023 to represent EmPOWER, and continued from 2024-2050 25% of new sales of all natural gas appliances are assumed to be efficient by 2030	50% of new sales of all electric appliances are assumed to be efficient (e.g. EnergyStar) from 2015-2023 to represent EmPOWER (0% sales starting in 2024), same as Reference assumptions
Behavioral conservation and smart devices	10% reduction in energy services demand below Baseline Scenario in residential lighting, space heating, and water heating	5% reduction in energy services demand below Baseline Scenario in residential lighting, space heating, and water heating, same as Reference assumptions
Other non-stock sectors	20% reduction in electric energy consumption below Baseline Scenario by 2050	10% reduction in electric energy consumption below Baseline Scenario by 2023, same as Reference assumptions

	10% reduction in all other energy consumption below Baseline Scenario by 2050	
Industrial energy use	30% reduction below Reference Scenario by 2050	AEO 2017 reference scenario growth rates by fuel, same as Reference assumptions

Table 6-4. Policies and measures where 2030 GGRA Plan and No Building Decarbonization scenario are different

	2030 GGRA Plan	No Building Decarbonization Scenario
Building retrofits for high efficiency building shells	Improved building shells for all new construction and 25% of retrofit buildings by 2030 to reflect efforts beyond building improvement	Improved building shells in all new construction by 2030 to represent continued building code improvement, same as Reference assumptions
Building electrification	50% of new sales of electric heat pump by 2030 and 80% by 2040, replacing natural gas furnaces and boiler sales	None, same as Reference assumptions

Table 6-5. Policies and measures where 2030 GGRA Plan and No MHDV Electrification scenario are different

	2030 GGRA Plan	No MHDV Electrification Scenario
Medium- and heavy-duty vehicle electrification	Aggressive sales of ZEV MHDVs to meet the ZEV Truck Mandate (35% sales by 2030 and 100% by 2050); truck stop electrification and zero-emission truck corridors	None, same as Reference assumptions

Table 6-6. Policies and measures where 2030 GGRA Plan, No CARES scenario and Reference RGGI scenario are different

	2030 GGRA Plan	No CARES Scenario	Reference RGGI Scenario
Clean Electricity Standard	75% Clean and Energy Standard (CARES) by 2030, 100% by 2040; carveout for in-state	50% RPS by 2030 (Clean Energy Jobs Act), same as Reference assumptions	Same as 2030 GGRA Plan

	clean energy resources reaching 10% by 2030 and 30% by 2040		
RGGI	Accelerated RGGI cap that achieves 100% reductions by 2040	Same as 2030 GGRA Plan	30% cap reduction from 2020 to 2030, same as Reference assumptions