Energy+Environmental Economics

Maryland Pathways
Policy Scenario 4

July 16th, 2019

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Agenda

- Background and Approach
- Scenario Design
- GGRA Draft Plan Results

BACKGROUND AND APPROACH

Background

- **The goal of this project is to quantify energy and emissions impacts from Maryland's current and potential future policies in the E3 PATHWAYS model**
- **The PATHWAYS modeling framework allows for:**
  - Detailed tracking of existing and future household appliances and vehicles
  - Hourly treatment of electricity sector
  - Comprehensive emissions accounting in buildings, transportation, industry, electricity generation, non-energy, and forestry
- **Reference Scenario (current policy case) was modeled in 2017, Mitigation Scenarios were modeled in 2018-2019**

What is Pathways modeling?

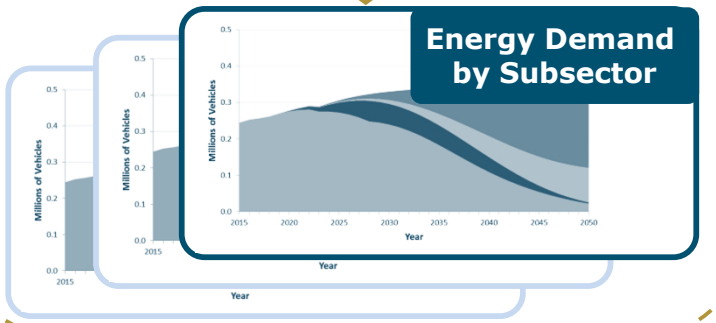
- Bottom-up, user-defined, non-optimized scenarios test "what if" questions
- Focus is on comparing user-defined policy and consumer adoption scenarios and tracking physical accounting of energy flows within all sectors of the economy
- Economy-wide model captures interactions within sectors (e.g. VMT reductions and electric vehicle sales) and between sectors (e.g. new vehicle electrification and cleaner electricity supply)
- Includes accounting of GHG emissions associated with energy and non-energy/non-combustion activities
- Economy-wide focus does not capture impacts of individual policies

Basic Energy Modeling Framework

Integrated Emissions Analysis

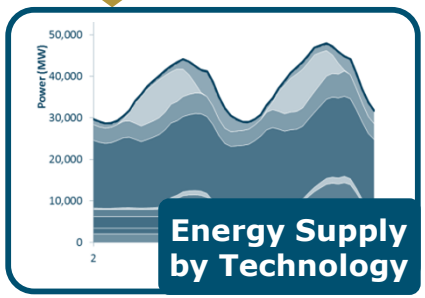
Technology Energy Demand

Scenario assumptions over time

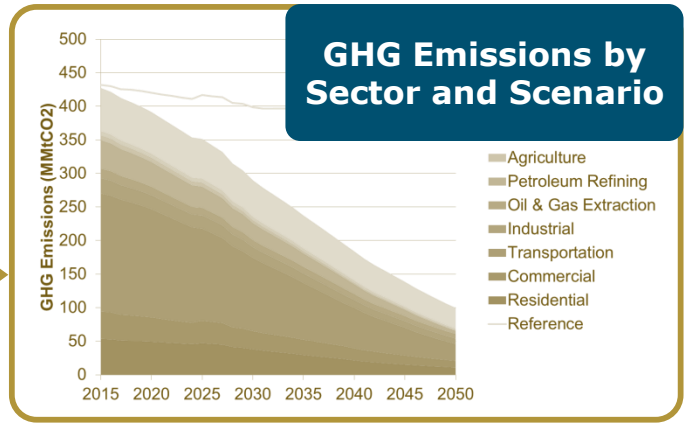


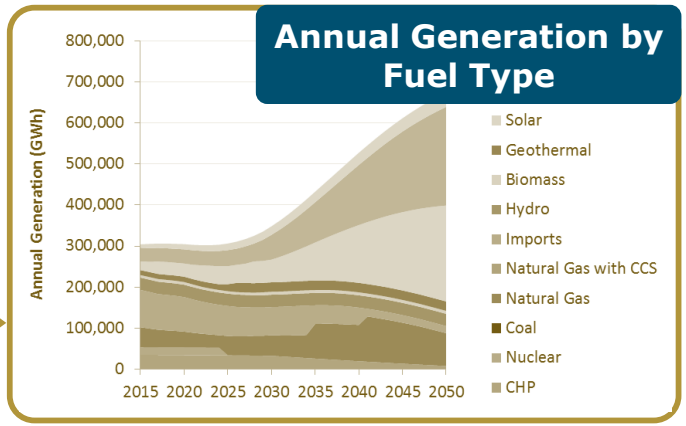
Electricity Supply

Pipeline Supply and Other Fuels



Sample Outputs:





SCENARIO DESIGN

Scenario Philosophies

- **Reference Scenario:** Major existing policies
- **Policy Scenario 1:** Extension of current program framework
- **Policy Scenario 2:** New programs and changing program frameworks (long-term measures to reach 2050 GHG goal)
- **Policy Scenario 3:** Carbon price and complementary policies (Climate Commission Scenario)
- **Policy Scenario 4:** GGRA Draft Plan

Policy Scenario 1 Measures

- **Philosophy: Extension of current program framework**
- **Includes:**
  - Continued effort for energy efficiency in buildings
  - Additional ZEV sales for light-duty vehicles
  - Reduction in vehicle-miles traveled and other MDOT measures
  - 50% RPS by 2030 (2017 Session HB1435/SB0732)
  - Smart Growth (75% compact development goal)
  - Additional acreage in forest management and healthy soils conservation practices

Policy Scenario 2 Measures

- **Philosophy: New programs and changing program frameworks (designed to reach 2050 GHG goal)**
- **Includes:**
  - All measures from Policy Scenario 1
  - Incremental mitigation actions
    - Additional ZEVs in LDVs, HDVs, and buses
    - Additional reductions in vehicle-miles traveled (VMT)
    - Advanced sustainable biofuels
    - 100% Clean and Renewable Energy Standard (CARES) in electricity supply
    - Additional acreage in forest management and healthy soils conservation practices

Policy Scenario 3 Measures

- **Philosophy: Carbon price in addition to complementary policy**
- **Includes:**
  - All measures from Policy Scenario 1
  - Escalating carbon price, translating into direct and indirect impacts in Maryland
    - Direct impacts to energy consumption based on higher fuel prices
    - Indirect impacts based on revenue being used for mitigation programs in Maryland

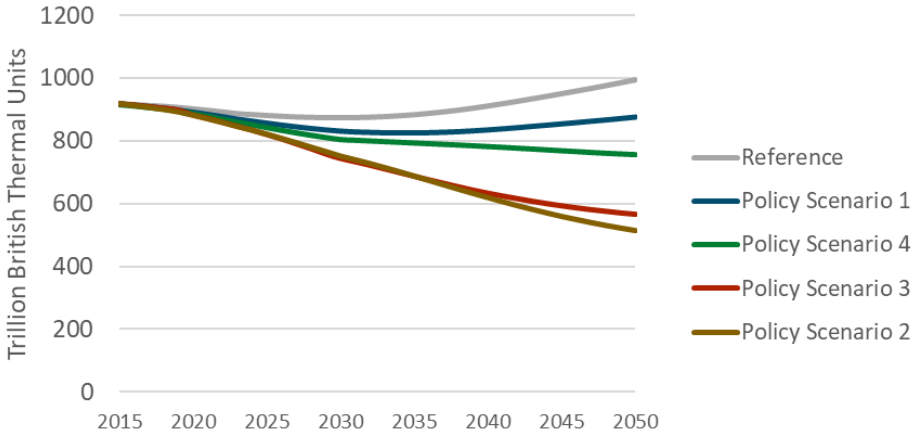
Policy Scenario 4 Measures

- **Philosophy: Draft GGRA Plan, draws upon state agency measures and Clean and Renewable Energy Standard**
- **Includes:**
  - All measures from Policy Scenario 1
  - Incremental mitigation actions
    - Additional ZEVs in LDVs, HDVs, and buses
    - Additional reductions in vehicle-miles traveled (VMT)
    - 100% Clean and Renewable Energy Standard (CARES) in electricity supply
    - Additional acreage in forest management and healthy soils conservation practices

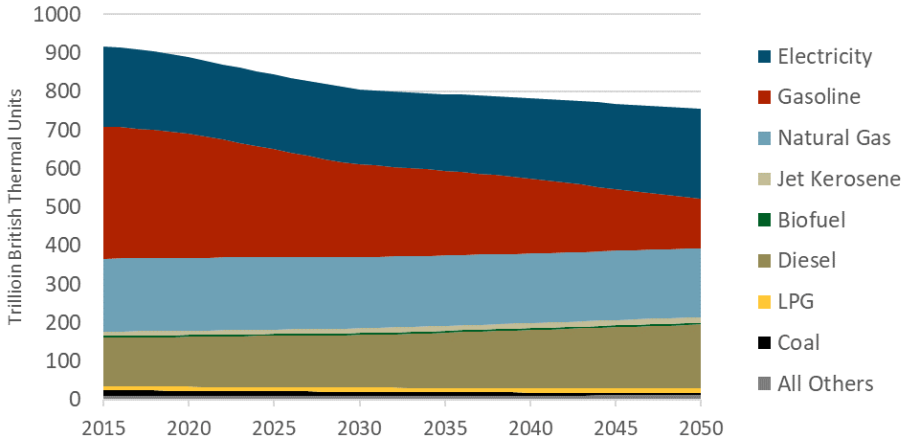
GGRA DRAFT PLAN RESULTS

Policy Scenario 4 Measures
Moderate Efficiency and Fuel Switching

Total Energy Consumption by Scenario



Total Energy Consumption by Fuel Policy Scenario 4

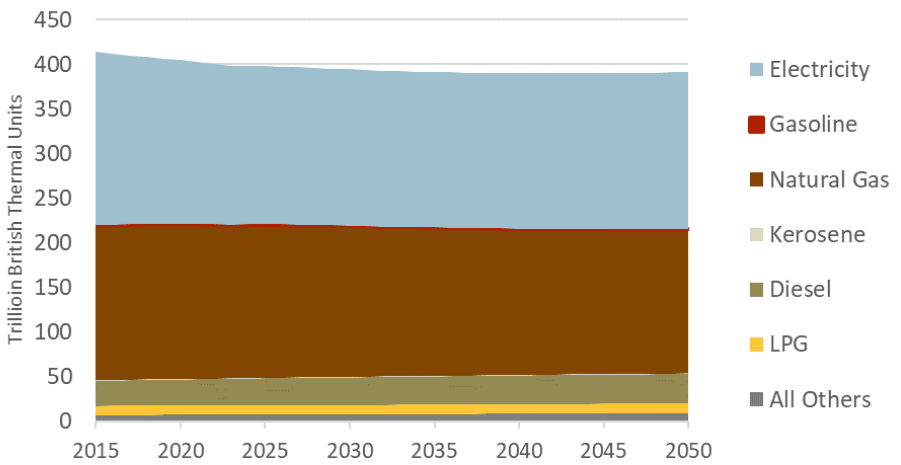


- PS4 shows reduction in energy consumption beyond PS1 due to more aggressive transportation measures
  - 3% reduction in 2030 and 13% in 2050 relative to PS1

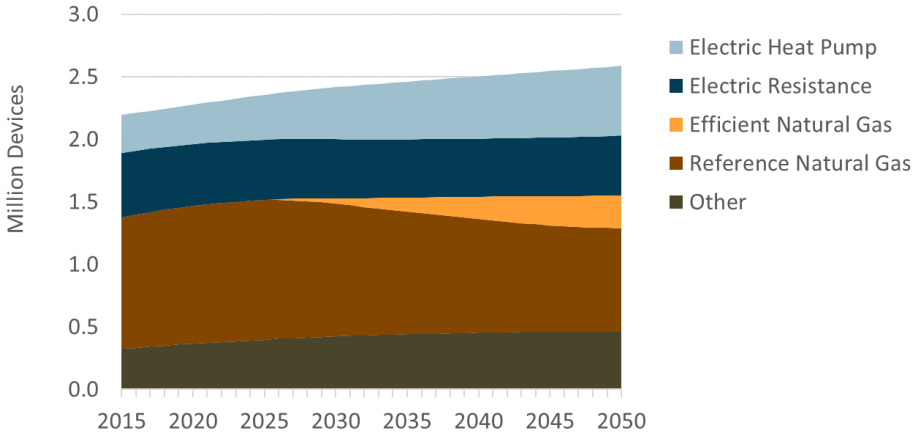
- Significant reduction in gasoline, and slight reduction in natural gas is due to increasing adoption of light-duty ZEVs and heat pumps, and energy efficiency measures

Policy Scenario 4 Measures
Building Efficiency and Electrification

Total Building Energy Consumption by Fuel



Total Space Heating Stocks by Type



- PS4 shows reduction in building energy consumption by 5% even with increasing number of building appliance due to both conventional efficiency and moderate increase in sales of electric space heaters

- The transition in space heating includes moderate increase in sales of electric heat pump space heaters and efficient natural gas fired space heaters

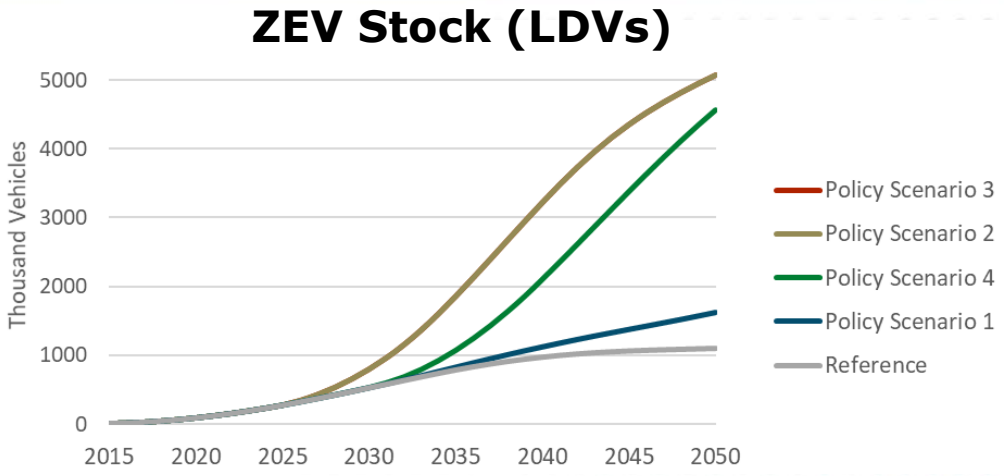
Policy Scenario 4 Measures
Light Duty ZEV adoption and VMT Reduction

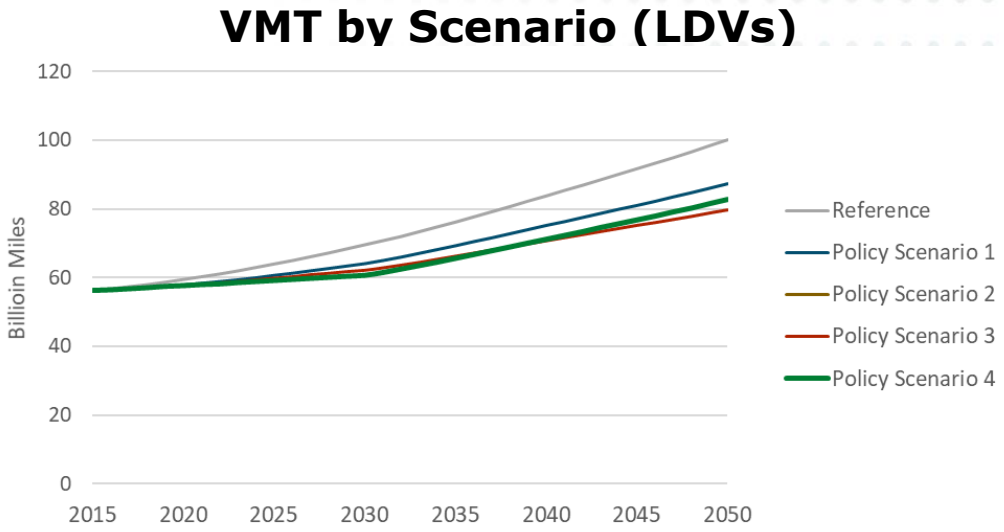
Increased Sales of ZEVs

- New sales of EVs and PHEVs gradually increase to 20% by 2030 (same as PS1) and 100% by 2050 (same as PS2 and PS3)
- 270,000 ZEVs by 2025, 530,000 ZEVs by 2030, 4,600,000 ZEVs by 2050

Reduction in VMT

- Reduction of annual LDV vehicle-miles traveled by 13% relative to Reference in 2030 and through 2050 (similar to PS2)



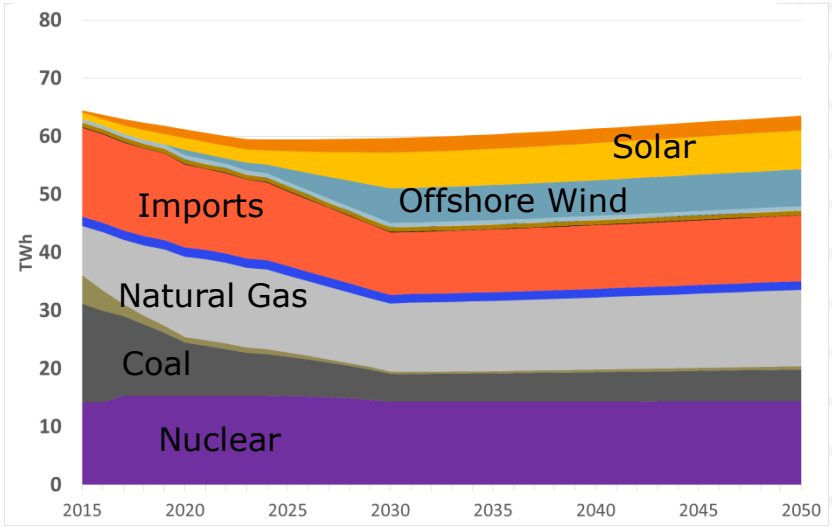


Policy Scenario 4 Measures
Electric Supply

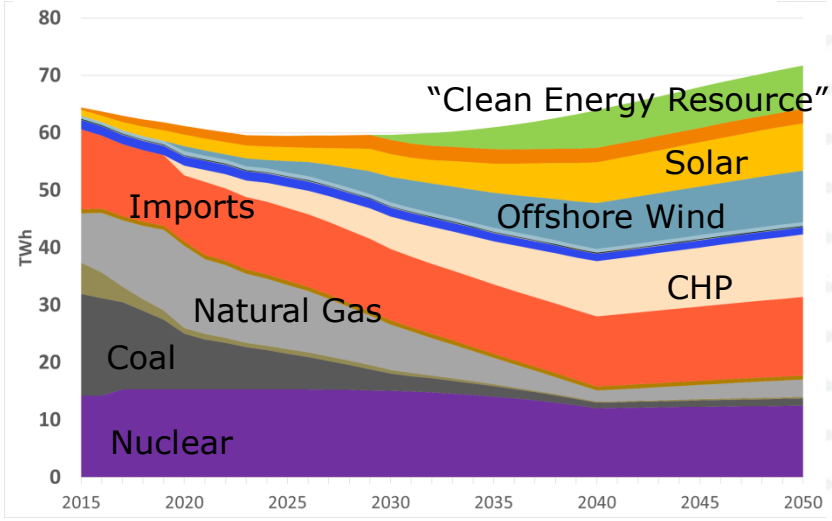
Illustrative 100% "Clean and Renewable Energy Standard" (CARES) by 2040

- 75% CARES in 2030 and 100% in 2040, with solar, offshore wind, and Tier 1 REC carveouts, plus new clean energy resources (new nuclear, carbon capture, and combined heat and power) and existing nuclear.
- Coal and Oil CT resources are phased out as RGGI cap tightens and renewable generation increases
- CARES requirement not met by Tier 1 resources is served by CHP resources, Tier 1 Solar until 2030 and a generic "Clean Energy Resource" beyond 2030
  - CHP resource availability is based on potential estimated in DoE study
  - Generic "Clean Energy Resource" will depend on available technologies at that time

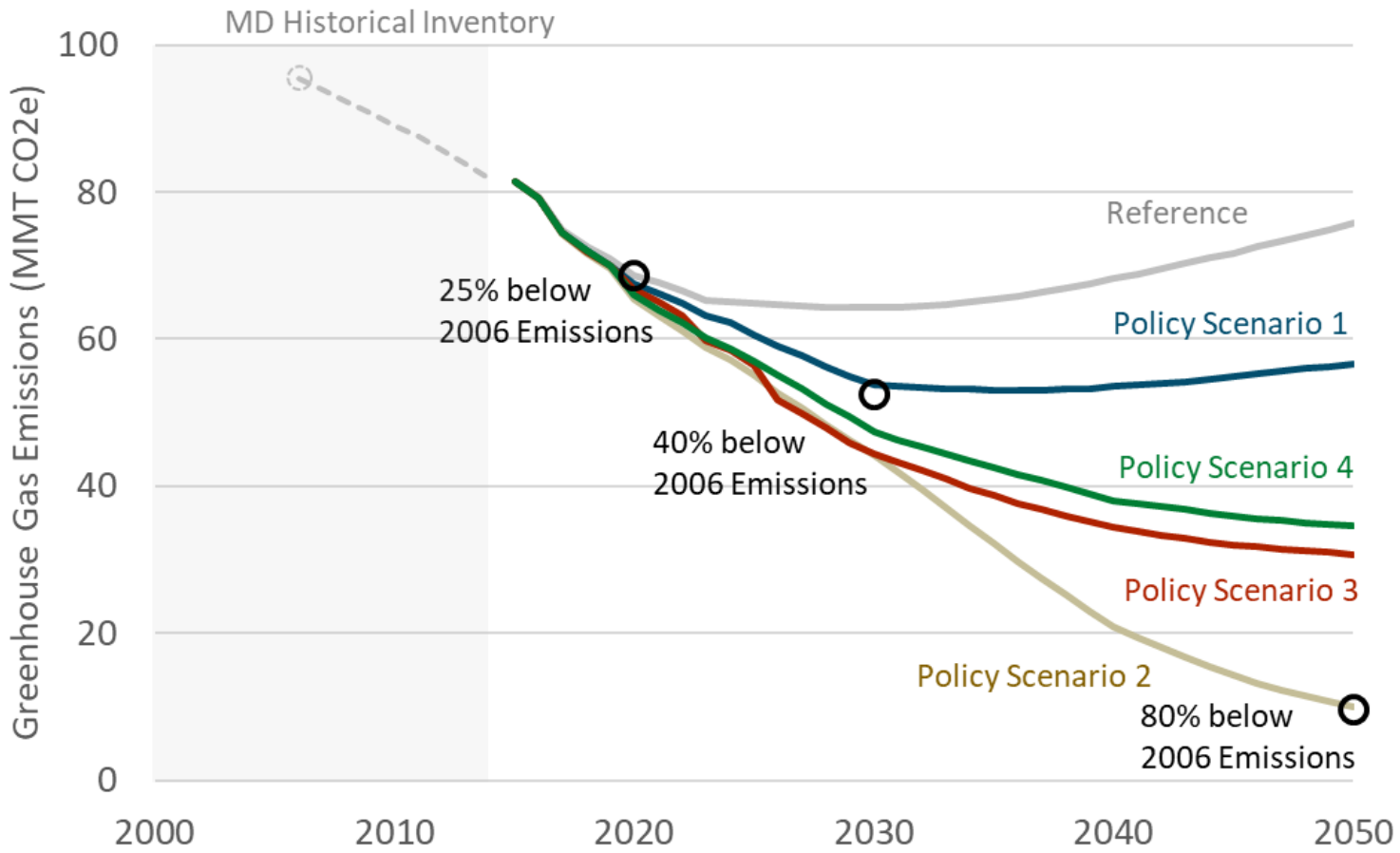
Policy Scenario 1 Gen by Resource



Policy Scenario 4 Gen by Resource



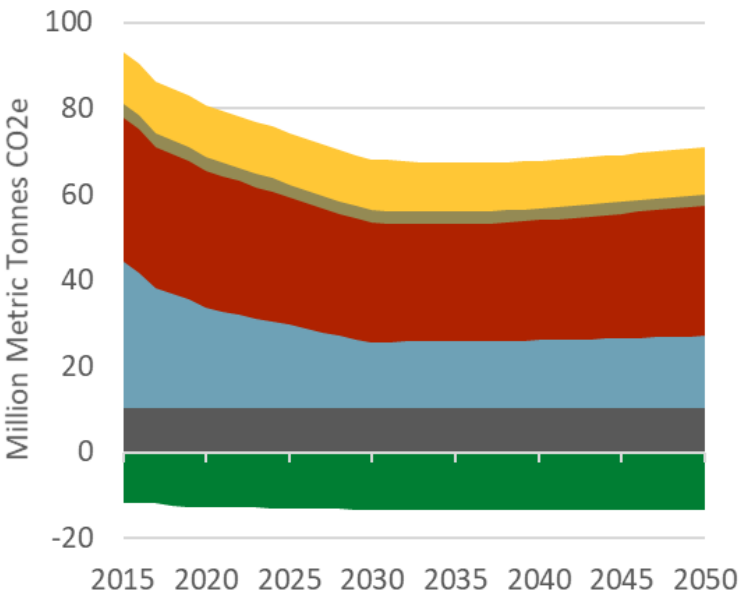
Total Net GHG Emissions by Scenario



PS4 Gap in 2020: -2.6 MMT (overachieved goal)
PS4 Gap in 2030: -5.1 MMT (overachieved goal)
PS4 Gap in 2050: 24.9 MMT

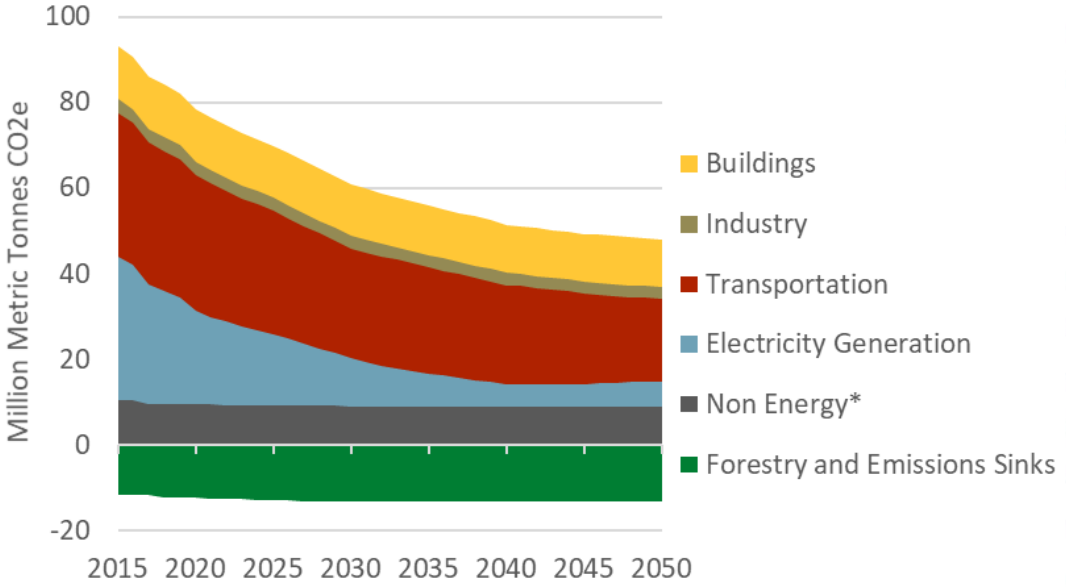
Total GHG Emissions by Sector

Policy Scenario 1



- The Buildings and Industry sectors have the same direct GHG emissions as in PS4 as in PS1
- The Transportation sector in PS4 has the largest reduction in direct GHG emissions of 11 MMT CO2 relative to PS1 by 2050

Policy Scenario 4

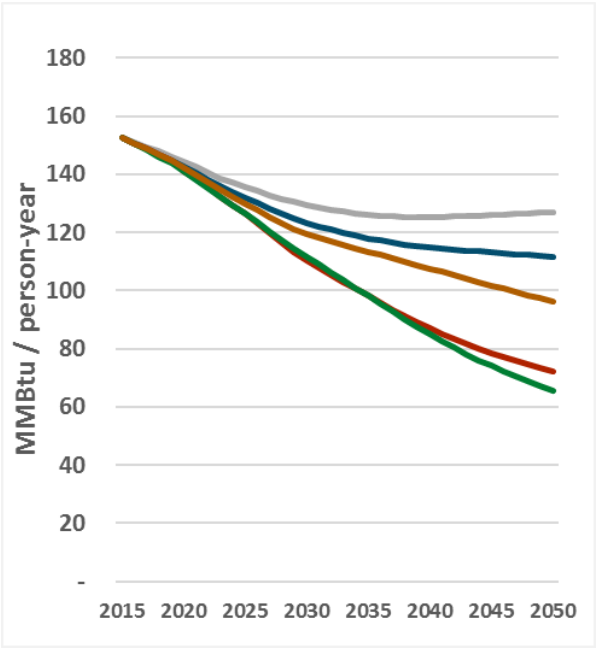


- Emissions associated with new electric demands (e.g. EVs) are captured in "Electricity Generation" but a transition to cleaner electricity generation results in further reductions relative to PS1
- Forestry and Emissions sinks are enhanced in Policy Scenario 4 relative to PS1

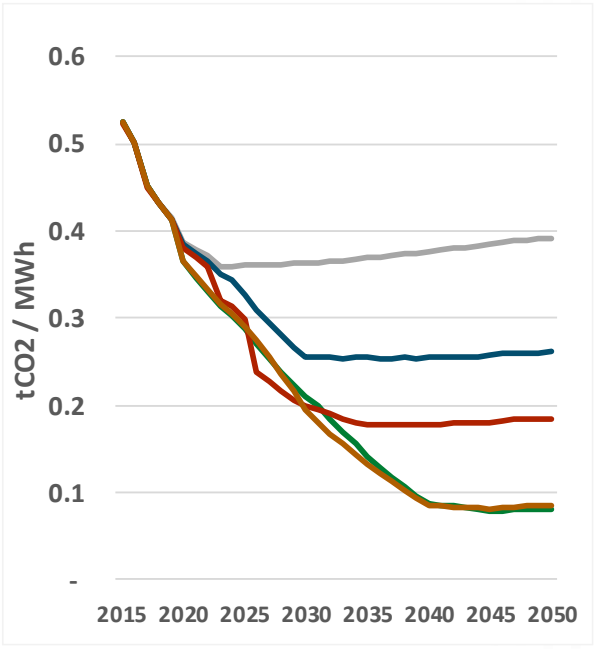
*Non Energy includes Agriculture, Waste Management, Industrial Processes and Fossil Fuel Industry emissions

Key Metrics: 3 Pillars of Decarbonization

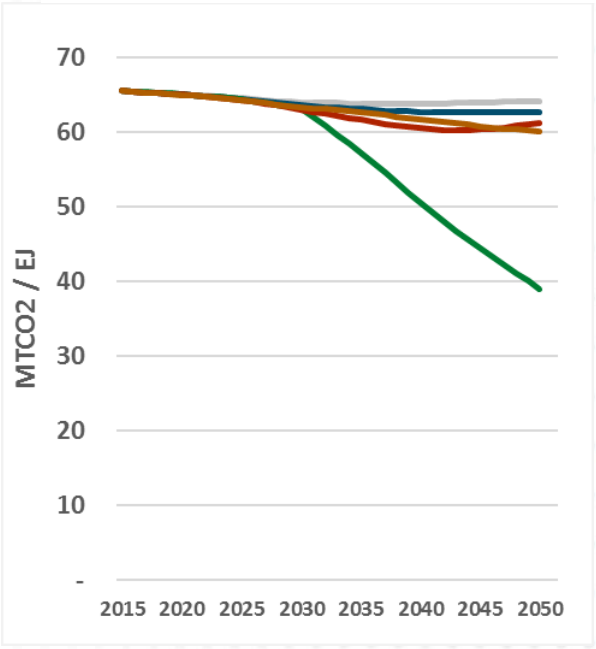
(1) Energy Efficiency
[Energy Consumption per person]



(2) Clean Electricity
[Metric ton/MWh]



(3) Clean Liquid and Gaseous Fuels
[Million Metric tonnes / EJ]



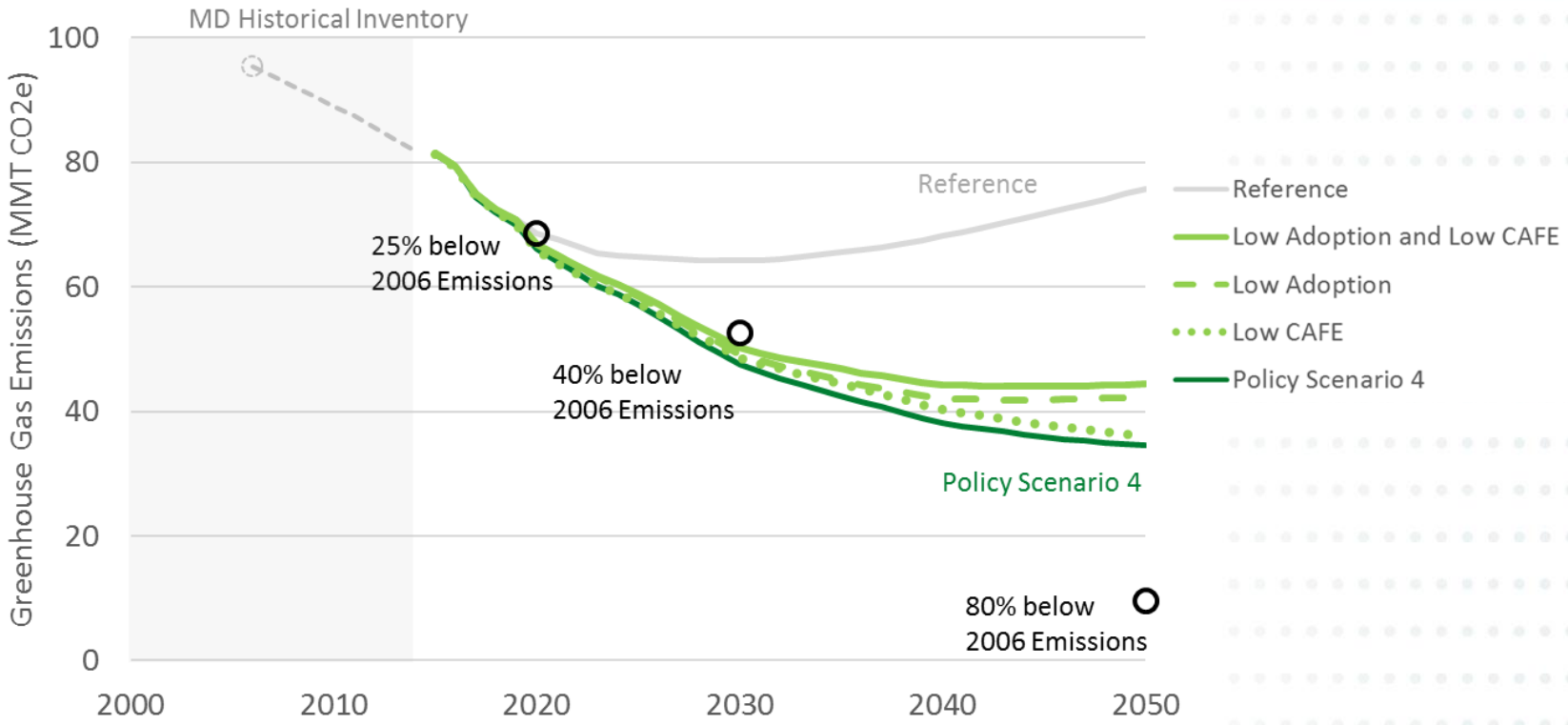
Reference Scenario
Policy Scenario 1
Policy Scenario 2
Policy Scenario 3
Policy Scenario 4

How robust are these findings to consumer adoption or federal action?

- **We ran three sensitivities on Policy Scenario 4 to test the impact on emissions of consumer adoption and federal action:**

1. **Low Adoption**: Evaluates the impact of achieving only half the projected sales of new electric vehicles and efficient household appliances.
2. **Low CAFE**: Evaluates the impact of removing the improvements in federal Corporate Average Fuel Economy standards for light-duty vehicles from 2021-2026.
3. **Low Adoption and Low CAFE**: Evaluates the combined impact of lower consumer adoption and lower fuel economy standards.

Impacts of lower consumer adoption and fuel economy standards



- Even with more conservative assumptions on consumer adoption and federal action on fuel economy standards, the measures and actions in Policy Scenario 4 are sufficient to meet Maryland's 2030 GHG target.
- By 2050, however, the lower levels of consumer adoption create a significant emissions gap as the state tries to reach its 2050 GHG goal.

Energy+Environmental Economics

Thank You!

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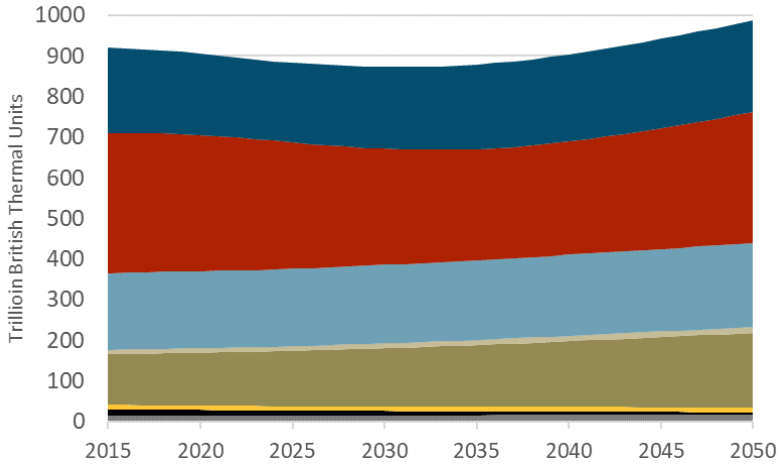
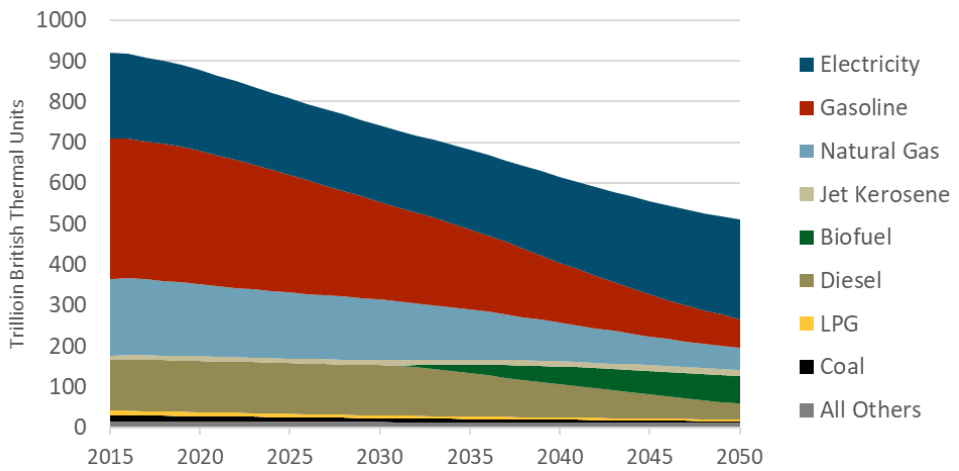
Appendix

Energy Consumption by Fuel and Scenario

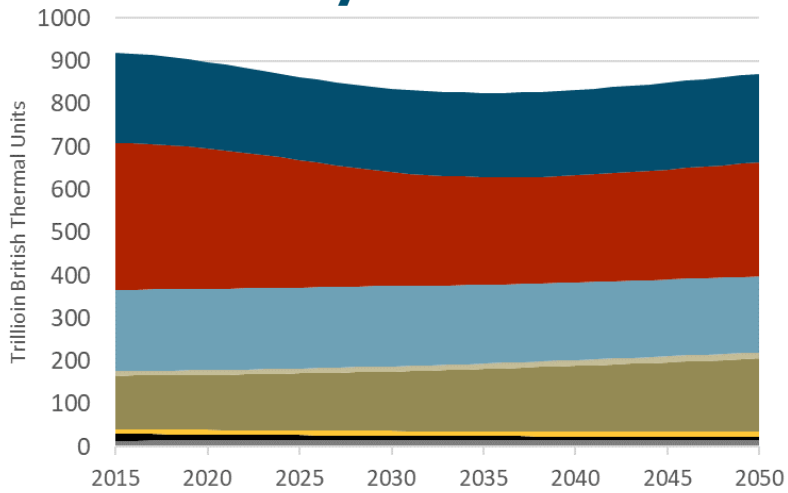
Reference



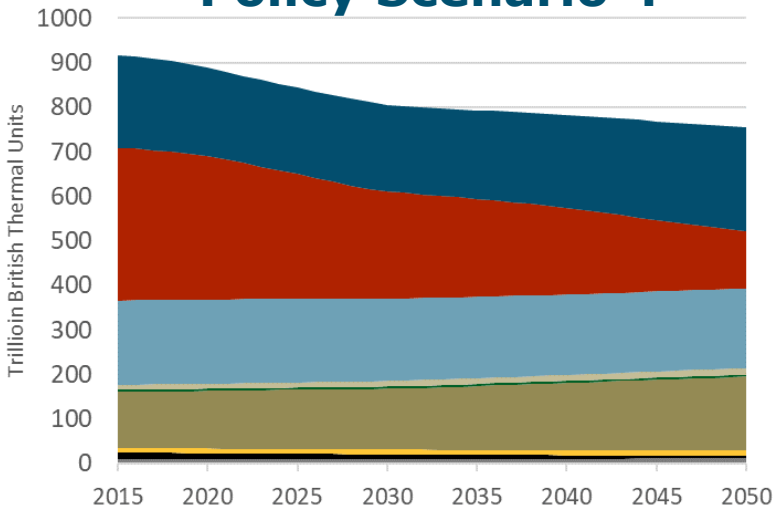
Policy Scenario 2



Policy Scenario 1



Policy Scenario 4

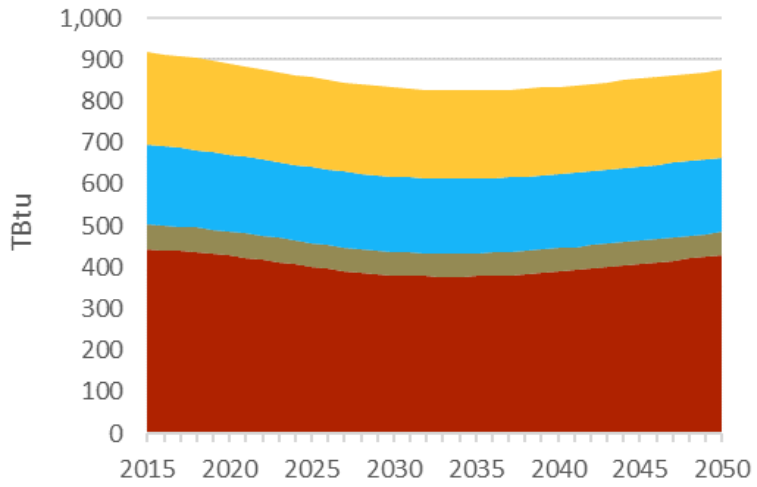


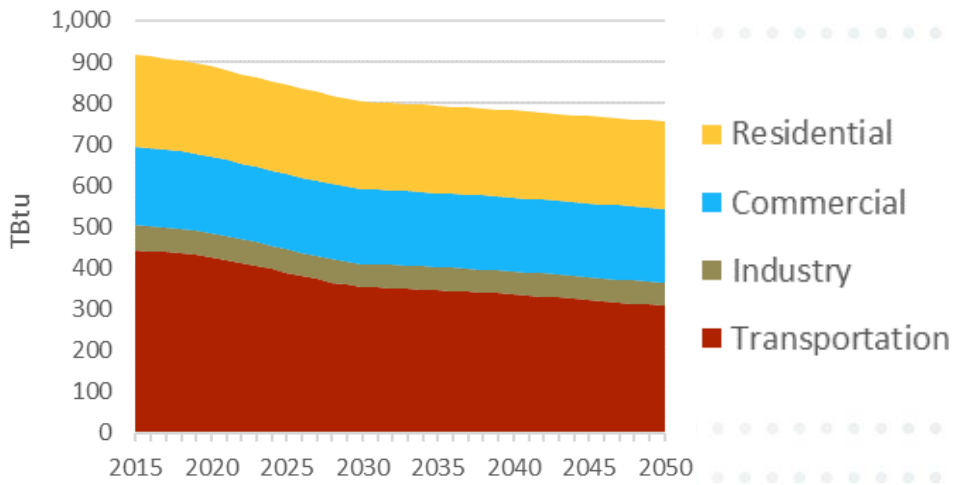
Energy Consumption by Sector
Policy Scenario 1 vs. Policy Scenario 4

Policy Scenario 1

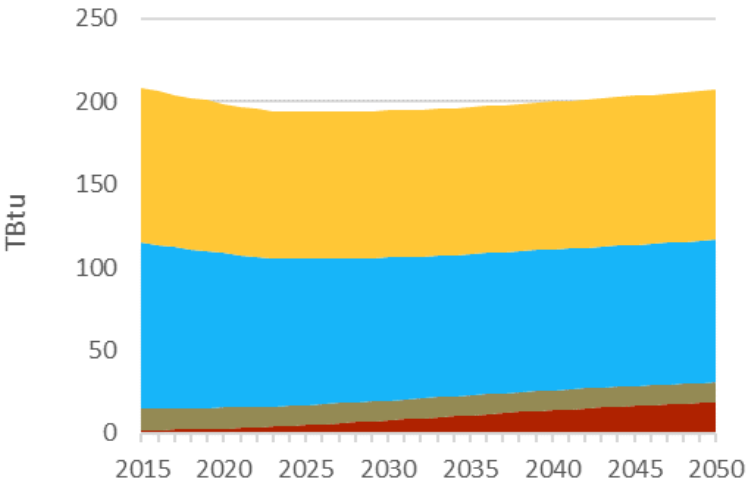
Policy Scenario 4

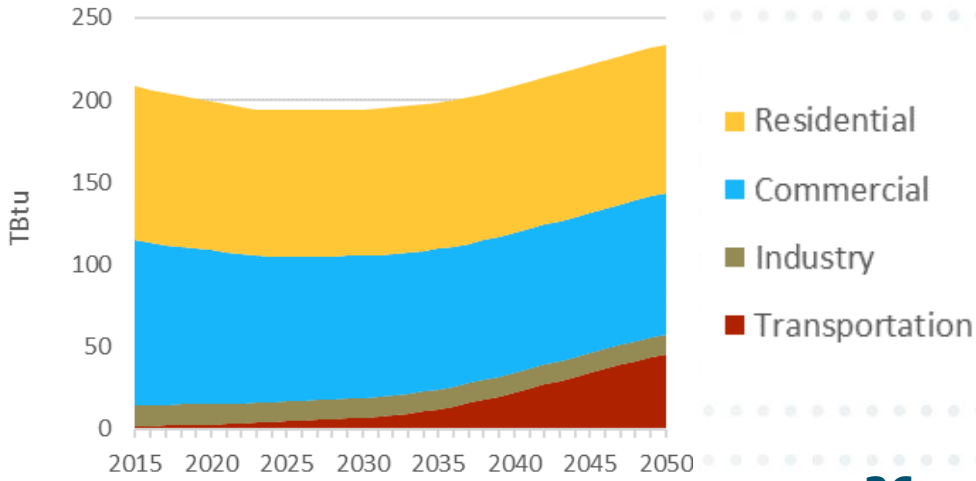
All Fuels





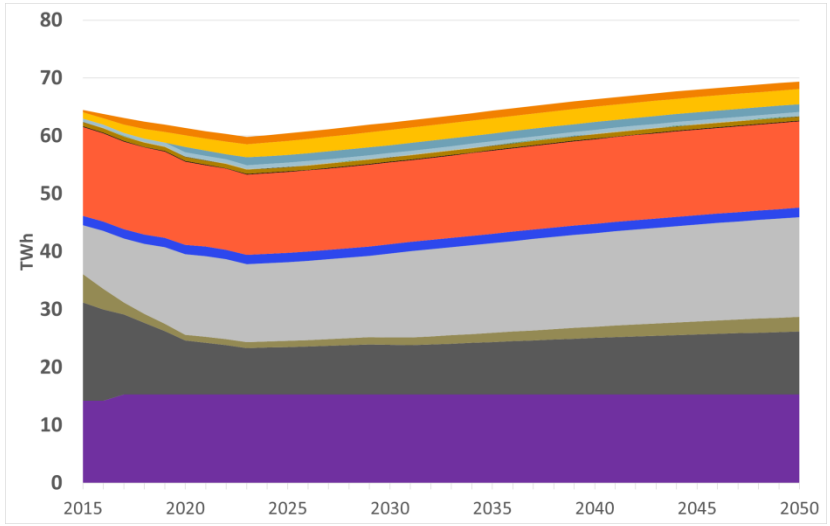
Electricity



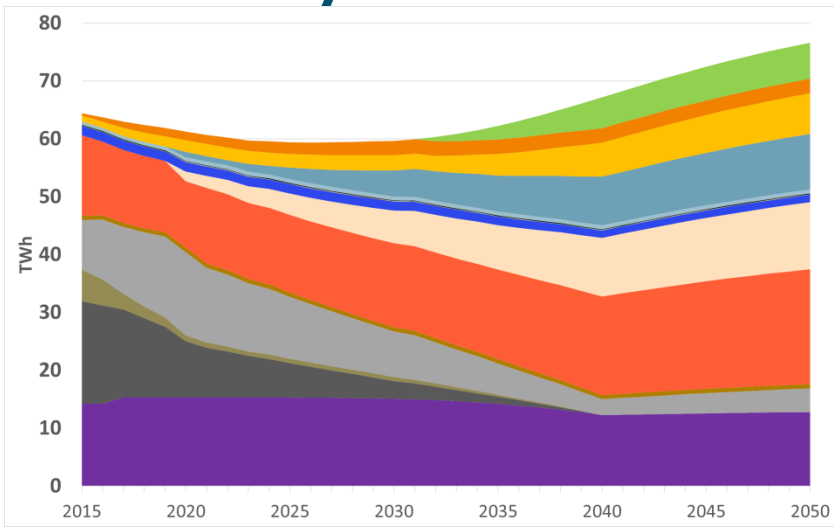


Electricity Generation by Source and Scenario

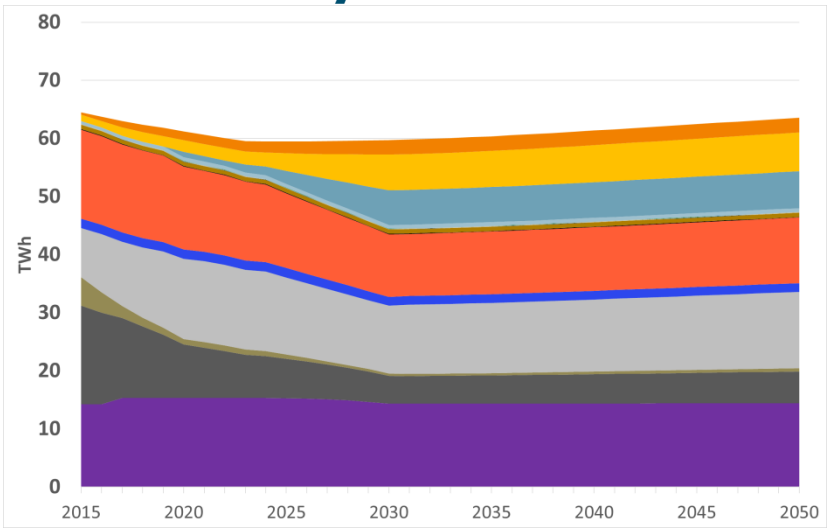
Reference



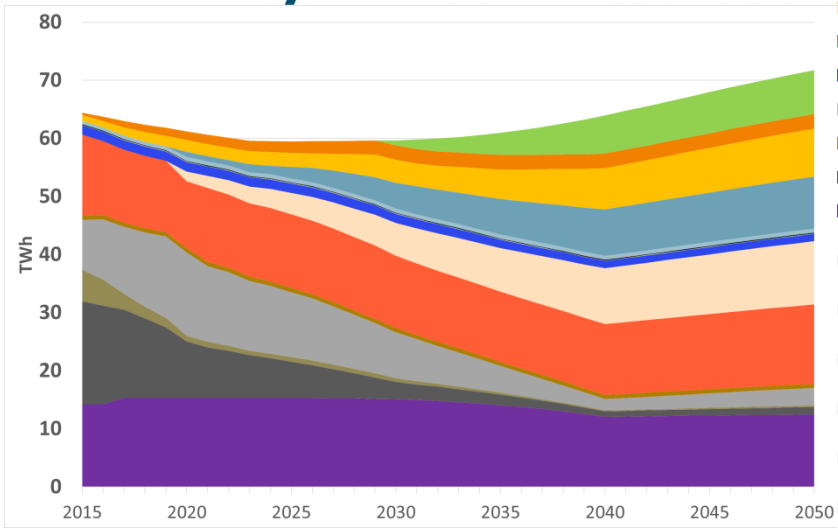
Policy Scenario 2

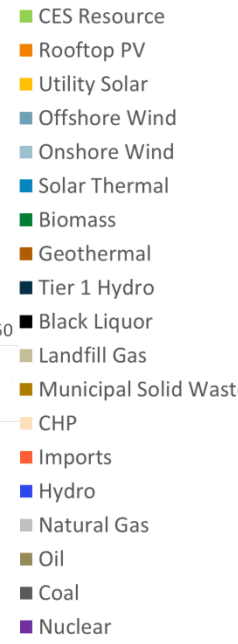


Policy Scenario 1



Policy Scenario 4

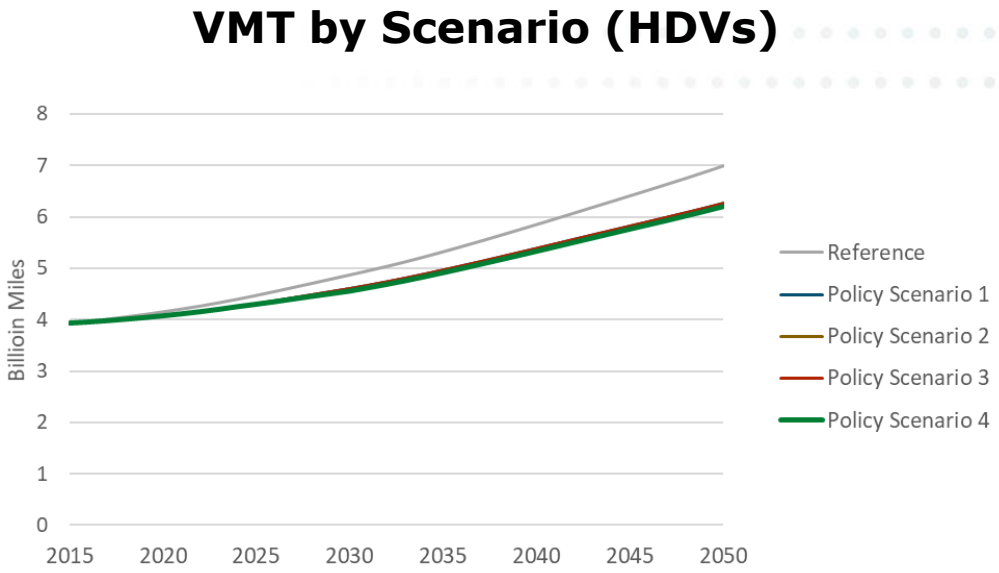




Policy Scenario 4 Measures
Heavy Duty ZEV adoption and VMT Reduction

Reduction in VMT

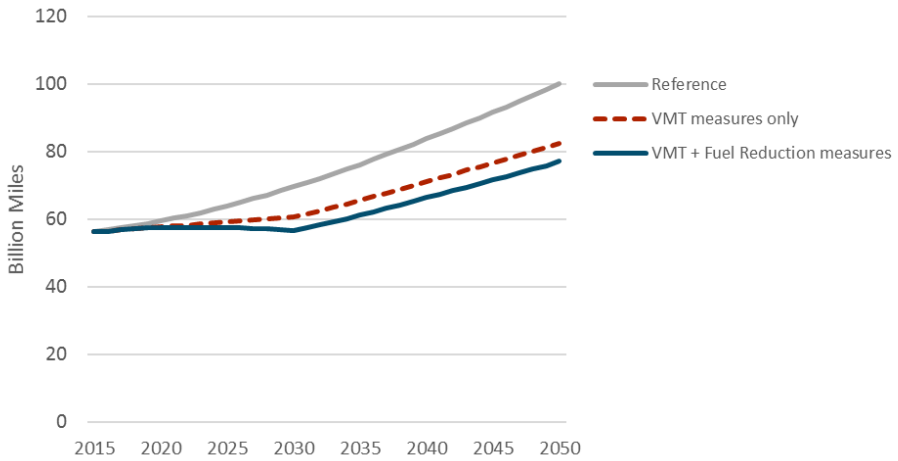
- Reduction of annual HDV vehicle-miles traveled by 6% relative to Reference in 2030 and through 2050 (same as PS2)



Modeling Maryland Department of Transportation (MDOT) Strategies

- Two types of MDOT measures are represented:
  - (1) **VMT measures** that directly reduce vehicle-miles traveled
  - (2) **Fuel Reduction measures** that directly reduce fuel consumption of gasoline or diesel vehicles.
- E3's bottom-up model of transportation and vehicles, both types of measures were translated into effective VMT reductions within the PATWHAYS model.

Total VMTs, Reference and Policy Scenario 4 (two types MDOT measures shown separately)

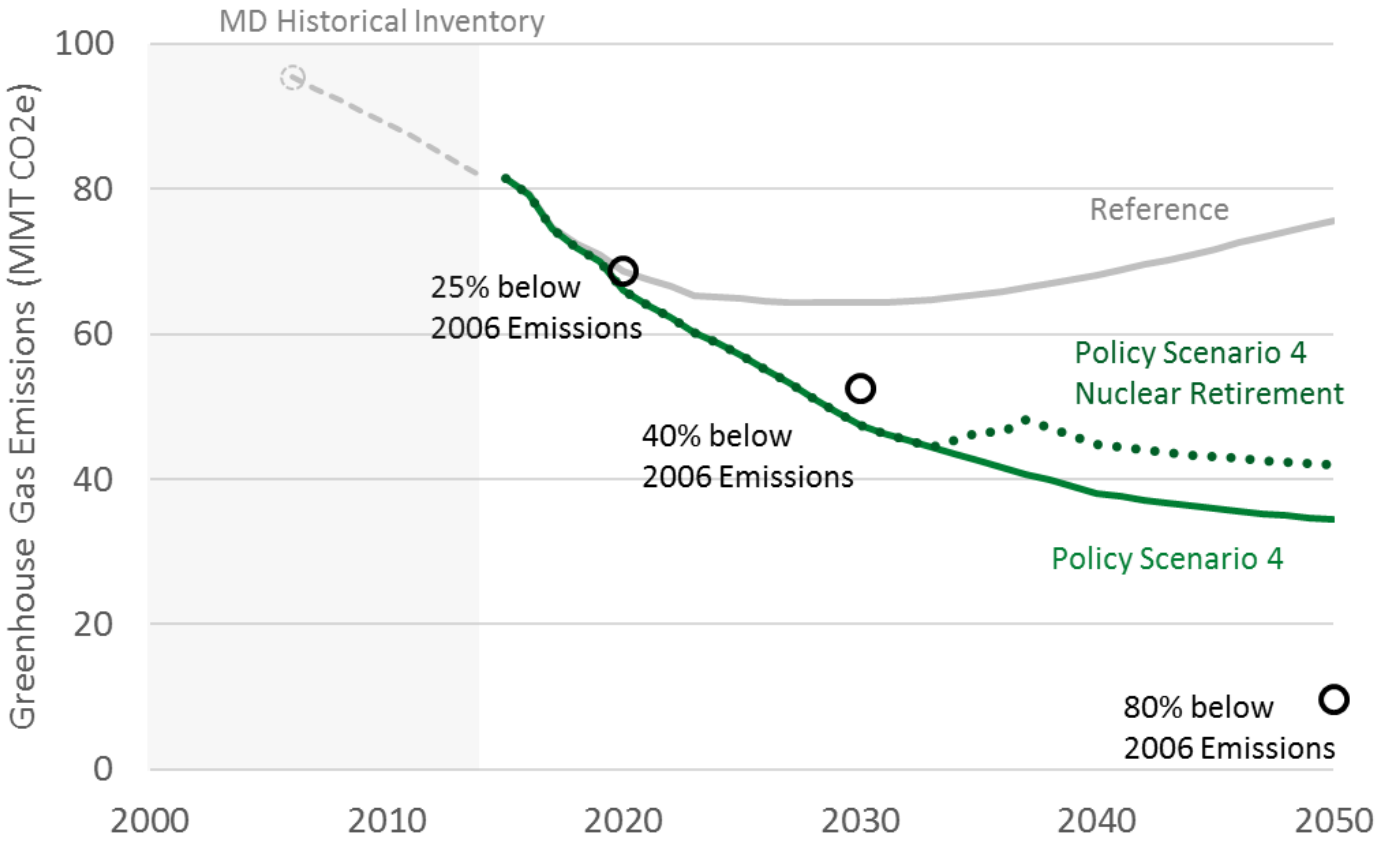


RGGI Expansion in Policy Scenarios 2 and 4

- **In Policy Scenario 2, RGGI caps continue to decline through 2050 in Maryland**
  - Results in the shutdown of in-state coal and oil generation and increased imports (not covered by RGGI cap)
- **In Policy Scenario 4, RGGI caps freeze at 2030 levels, but oil and coal resources continue to ramp down post-2030 to make room for additional CARES resources**
- **In both cases, the emissions intensity of imports declines 40% from 2025 (879.3 lbs / MWh) to 2045 (527.6 lbs / MWh), reflecting increasingly stringent RGGI caps throughout the rest of PJM**

Impacts of Calvert Cliff Retiring

- The impact of Calvert Cliffs retiring is about 7.5 million metric tonnes CO2e in 2050, widening the gap to reach the state's GHG target.



Scenario Assumptions
Reference Scenario

	Reference Scenario (Existing Policies)
Renewable Portfolio Standard	25% RPS by 2020
RGGI	30% cap reduction from 2020 to 2030
Nuclear power	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)
Rooftop PV	Moderate growth from current levels of 200 MW (2% a year; 400 MW in 2050)
Energy Efficiency (Res., Com. & Industrial)	Calibrated to EmPOWER filing targets 50% of electric appliance sales are high-efficiency 2015-2023, 5% residential behavioral conservation by 2030, 10% reduction below baseline for electricity in non-stock sectors by 2050
Electrification of buildings (e.g. NG furnace to heat pumps)	None
Transportation	Federal CAFÉ standards for LDVs by 2026, Meets ZEV mandate by 2025 (270,000 ZEVs)
Other transportation sectors (e.g. aviation)	AEO 2017 reference scenario growth rates by fuel
Industrial energy use	AEO 2017 reference scenario growth rates by fuel
Biofuels	Existing ethanol and biodiesel blends, but no assumed increase
Other (fossil fuel industry, industrial processes, agriculture, waste management, forestry)	Assume held constant at MDE 2014 GHG Inventory levels, with specific projections for forest management and healthy soils

Scenario Assumptions
Policy Scenario 1

	Policy Scenario 1 (updates from Reference in Bold)
Renewable Portfolio Standard	**50% RPS by 2030**
RGGI	30% cap reduction from 2020 to 2030
Nuclear power	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)
Rooftop PV	**1500 MW in 2030**
Energy Efficiency (Res., Com. & Industrial)	**50% of electric appliance sales are high-efficiency 2015-2050 (25% for natural gas), 10% residential behavioral conservation by 2050, 20% reduction below baseline for electricity in non-stock sectors by 2050 (10% for natural gas)**
Electrification of buildings (e.g. NG furnace to heat pumps)	**Moderate electrification – increase of 15% in electric heat pump sales by 2050 (replacing natural gas furnaces and boiler sales)**
Transportation	Federal CAFÉ standards for LDVs by 2026, **Meets ZEV mandate by 2025 (270,000 ZEVs), increases to 1.4 Million ZEVs by 2050**
Other transportation sectors (e.g. aviation)	AEO 2017 reference scenario growth rates by fuel
Industrial energy use	AEO 2017 reference scenario growth rates by fuel
Biofuels	Existing ethanol and biodiesel blends, but no assumed increase
Other (fossil fuel industry, industrial processes, agriculture, waste management, forestry)	**Forest management and Healthy soils sequestration**

Scenario Assumptions
Policy Scenario 2

	Policy Scenario 2 (updates from Reference in Bold)
Renewable Portfolio Standard	**75% CARES by 2040**
RGGI	**30% cap reduction from 2020 to 2030, additional 60% reduction from 2030 to 2050 results in all coal / oil going offline by 2040. Emissions intensity of imported electricity declines from 2025 to 2045, reflecting increased stringency of RGGI caps throughout PJM footprint**
Nuclear power	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)
Rooftop PV	**1500 MW by 2030**
Energy Efficiency (Res., Com. & Industrial)	**100% of electric and natural gas appliance sales are high-efficiency by 2030 and beyond, 10% residential behavioral conservation by 2050, 30% reduction below baseline for electricity in non-stock sectors by 2050**
Electrification of buildings (e.g. NG furnace to heat pumps)	**Aggressive electrification – 95% of electric heat pump sales by 2050 (replacing natural gas furnaces and boiler sales)**
Transportation	**Aggressive ZEV adoption – 100% sales of ZEVs in light-duty vehicles, and 95% sales of EVs and Diesel Hybrid in heavy-duty vehicles by 2050. VMT reduction programs – 11% reduction in LDV VMT below reference by 2030 and beyond**
Other transportation sectors (e.g. aviation)	**50% ZEVs in transit buses by 2030 and 50% of electric construction vehicles by 2050**
Industrial energy use	**30% efficiency gain (both electricity and natural gas) by 2050 due to Combined Heat & Power**
Biofuels	**Transition to advanced biofuels blended in diesel and natural gas**
Other (fossil fuel industry, industrial processes, agriculture, waste management, forestry)	**Aggressive forest management and healthy soils conservation practices, improvement in waste and manure management, and reduction in ODS Substitutes in compliance with SNAP by 2030 and Kigali by 2050**

Scenario Assumptions
Policy Scenario 3

- **Philosophy: Carbon Pricing Program in addition to complementary policy**
- **Includes:**
  - All measures from Policy Scenario 1 (see slide #32)
  - Escalating carbon price, translating into direct and indirect impacts in Maryland
    - Direct impacts to energy consumption based on higher fuel prices
    - Indirect impacts based on revenue being used for mitigation programs in Maryland

Scenario Assumptions
Policy Scenario 4

	Policy Scenario 4 (updates from Policy Scenario 1 in Bold)
Renewable Portfolio Standard	**100% CARES by 2040**
RGGI	**30% cap reduction from 2020 to 2030, with continued declines after 2030 as energy from CARES-compliant resources displaces coal and oil resources. Emissions intensity of imported electricity declines from 2025 to 2045, reflecting increased stringency of RGGI caps throughout PJM footprint**
Nuclear power	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)
Rooftop PV	**1500 MW by 2030**
Energy Efficiency (Res., Com. & Industrial)	**50% of electric appliance sales are high-efficiency 2015-2050 (25% for natural gas), 10% residential behavioral conservation by 2050, 20% reduction below baseline for electricity in non-stock sectors by 2050 (10% for natural gas)**
Electrification of buildings (e.g. NG furnace to heat pumps)	**Moderate electrification – increase of 15% in electric heat pump sales by 2050 (replacing natural gas furnaces and boiler sales)**
Transportation	**Moderate ZEV adoption by 2030 – 20% sales of ZEVs in light-duty vehicles by 2030 Aggressive ZEV adoption after 2030 – 100% sales of ZEVs in light-duty vehicles by 2050. VMT reduction programs – 11% reduction in LDV VMT below reference by 2030 and beyond**
Other transportation sectors (e.g. aviation)	**50% ZEVs in transit buses by 2030**
Industrial energy use	**20% electric efficiency gain and 10% NG efficiency gain by 2050 due to Combined Heat & Power**
Biofuels	Existing ethanol and biodiesel blends, but no assumed increase
Other (fossil fuel industry, industrial processes, agriculture, waste management, forestry)	**Aggressive forest management and healthy soils conservation practices, and reduction in ODS Substitutes in compliance with SNAP**