

Comprehensive Analysis of Maryland's Short- and Long-term Climate Stabilization and Clean Energy Goals and Investment Requirements

Center for Climate Strategies

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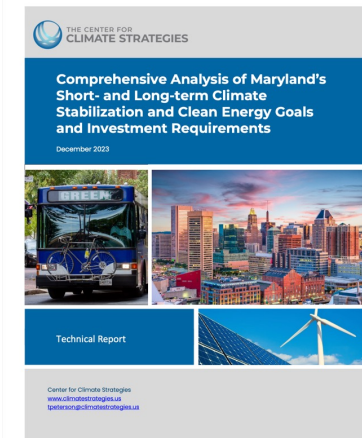
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CLIMATE STRATEGIES

Overview

- Comprehensive model
- Technologies and practices
- Infrastructure and facilities
- Climate, clean energy goals
- Forecast Current Policies
- Assess Additional Actions
- GHGs, energy, social costs and benefits, investments
- Data sources, methods, and key assumptions
- Future use of tools, data



Results

Strong potential
for ultimate goal
attainment

Beneficial
economic and
energy outcomes

Major avoided
costs for energy
and infrastructure

Significant up
front investment
costs

Savings equal to
*2/3 of all new
investment*

Challenges of
timing, capacity,
macro conditions

Uses of Assessment, Data, Tools

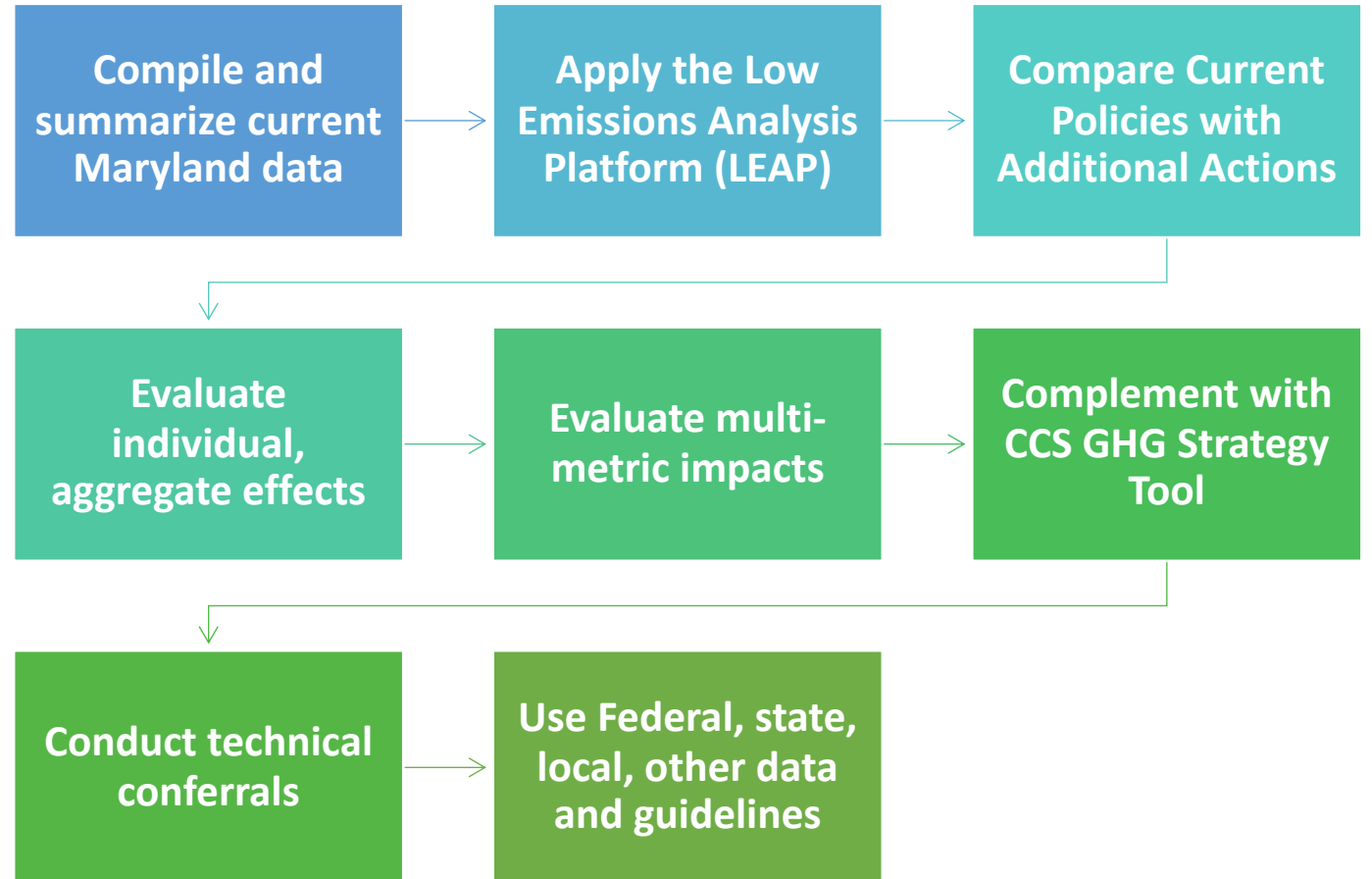
Policy, budget, and finance

Further develop and implement

Address critical new issues

Build capacity and consensus

Methods



GHG Emissions, BAU Current Policy Scenario



Current energy and economic trends in Maryland



Implementation status of state and federal policies



Energy, non-energy sector technologies and practices to 2050

Current Policies

Energy Supply

- Solar Carve out (Utility capacity expansion limited by PJM interconnection approval process)
- Community Solar system deployment
- RGGI RPS (Regional Greenhouse Gas Initiative renewable portfolio standard) goals, but only to extent modeled in Annual Energy Outlook 2023 (AEO or AEO2023)
- Planned retirements of coal-fired power plants
- Calvert Cliffs nuclear units assumed retired in 2034/36
- Promoting Offshore Wind Energy Resources (POWER) Act offshore wind expansion
- Implementation of energy storage

Buildings, Facilities, and Industry

- Continue implementation of EmPOWER, the electric utility-sponsored program for supporting energy efficiency improvements in the residential, commercial and industrial sectors
- State and Montgomery County BEPS
- All-electric Building Codes, Montgomery and Howard Counties
- AIM (American Innovation and Manufacturing) Act and MD HFC Regulations (non-energy industrial emissions reduction)

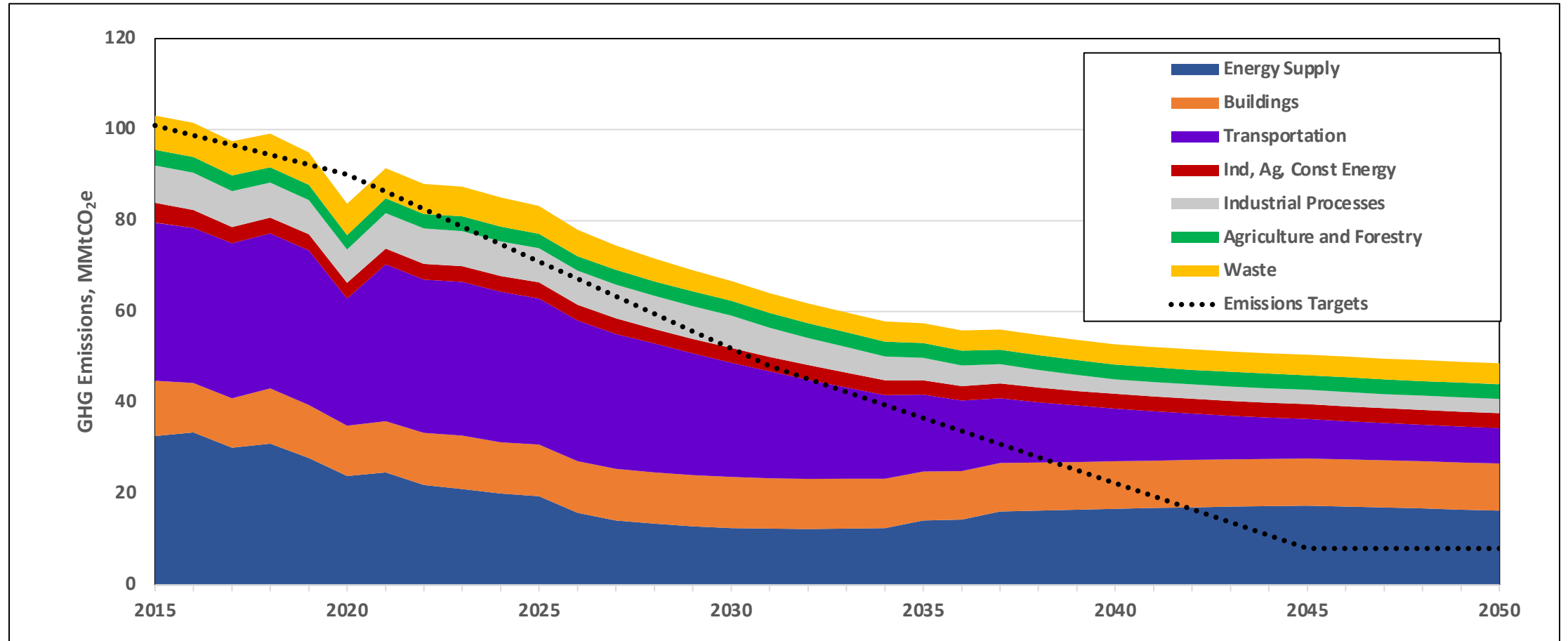
Transportation

- Implementation of Advance Clean Cars II (ACC II) rules
- CAFE (corporate average fuel economy) Standards, as included in AEO2023 modeling
- Advanced Clean Trucks (ACT) Rule
- WMATA (Washington Metro Transit Authority) vehicle electrification
- MTA (Maryland transit authority) vehicle electrification
- Construction of the Purple Line electrified light rail system
- Other ongoing trends and policies (some national and international), including motorcycle electrification, growth of e-bike usage, air transport electrification and use of sustainable aviation fuel, other transport electrification, ongoing electrification of lawn and garden equipment, and use of alternative fuels for marine shipping

Non-energy Sectors

- State 2035 Waste Generation and Diversion Goals
- MD Landfill Methane Rule
- Maryland 5 Million Tree Program

BAU/Current Policy Scenario



Maryland Climate and Clean Energy Goals

2031

- GHGs 60% below 2006 level by 2031 (CSNA and CPRG)

2035

- 100% Clean Energy (proposed)
- 100% Renewable Energy (under consideration)

2040

- 100% Renewable Energy (proposed)

2045

- Net-zero emissions

2050

- Net-zero emissions

New Actions

Energy Supply

- Utility Solar Expansion
- Expanded Offshore Wind
- Calvert Cliffs Life Extension
- RGGI Net Zero Generation by 2040
- Rooftop Solar Expansion
- Expanded Electricity Storage
- Natural Gas Generation Retired
- Retirement of Waste to Energy (WTE) Generation
- Liquefied Natural Gas (LNG) Liquefaction Electrification

Buildings, Facilities, and Industry

- Low Income (LI) Electrification
- All Electric Building Code Expansion
- Building Energy Performance Standards (BEPS)
- EmPOWER Restructuring
- Zero NOx Appliance Standards
- Cement Sector Electrification
- Cement Clinker Substitution
- Industrial Energy Efficiency and Electrification

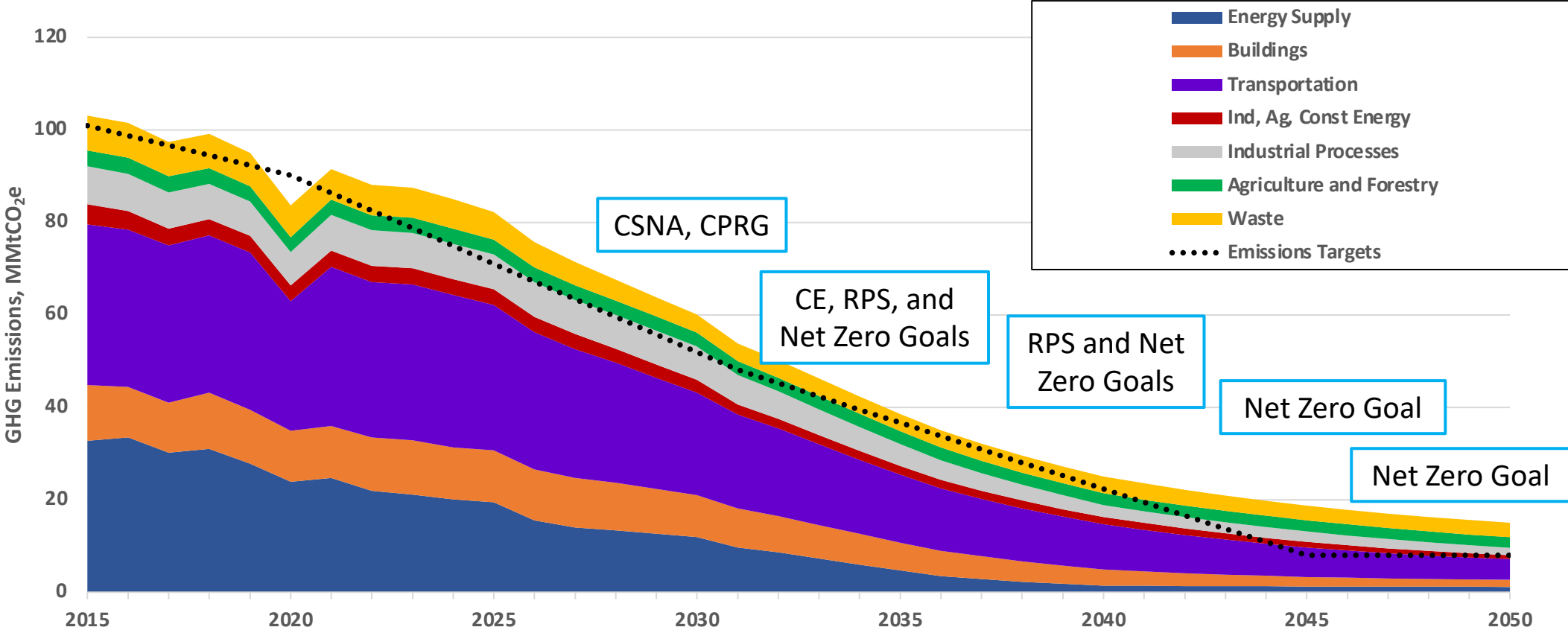
Transportation

- Vehicle Miles Traveled (VMT) Reduction
- Additional HDV, Bus, and Heavy Equipment Electrification
- Rail Electrification
- Freight Mode Shift and Rail Freight Electrification
- Other Transportation Electrification
- Air Transport Improvements
- Sustainable Aviation Fuel

Non-energy

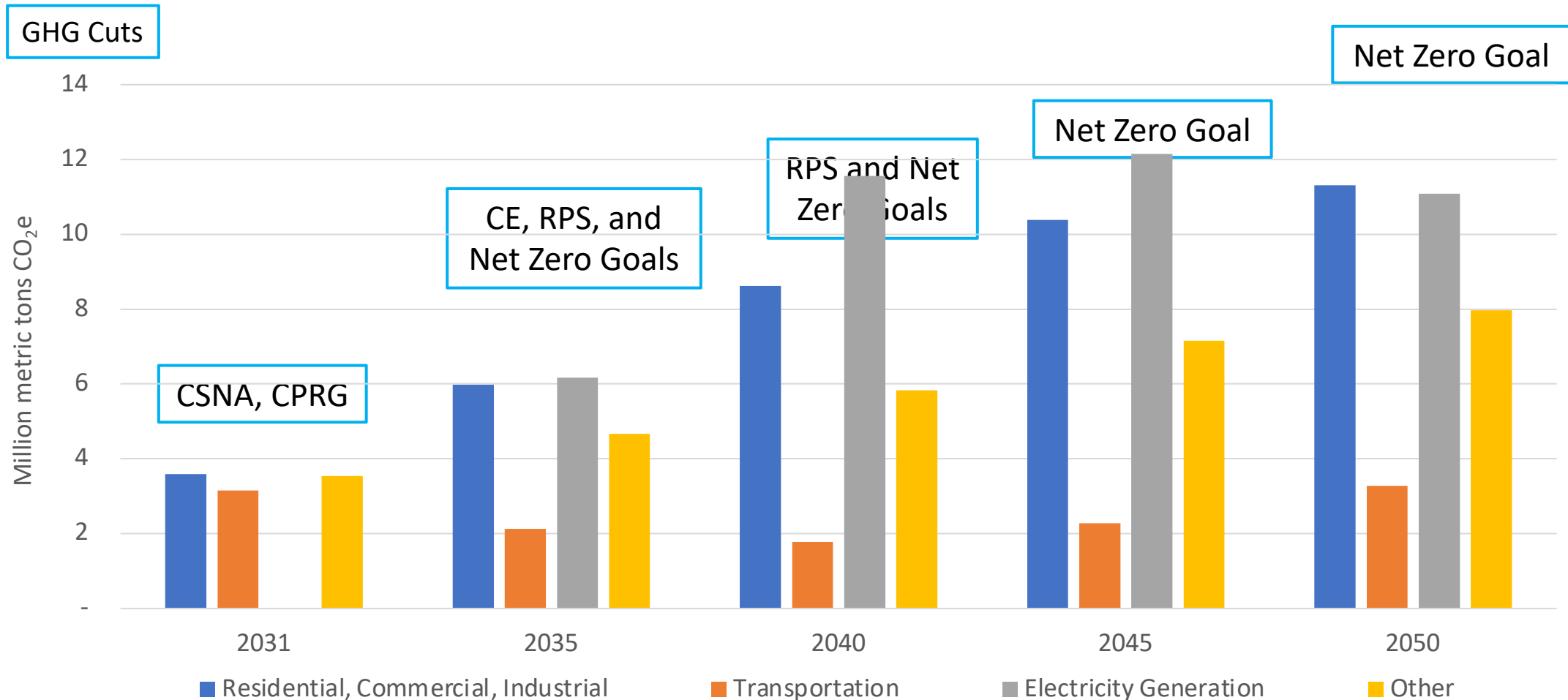
- Methane Capture from Landfills
- Expanded Composting
- Biogas Production and Use
- Enteric Methane Mitigation
- Biofertilizer
- Soil Management Program

Additional Actions Scenario

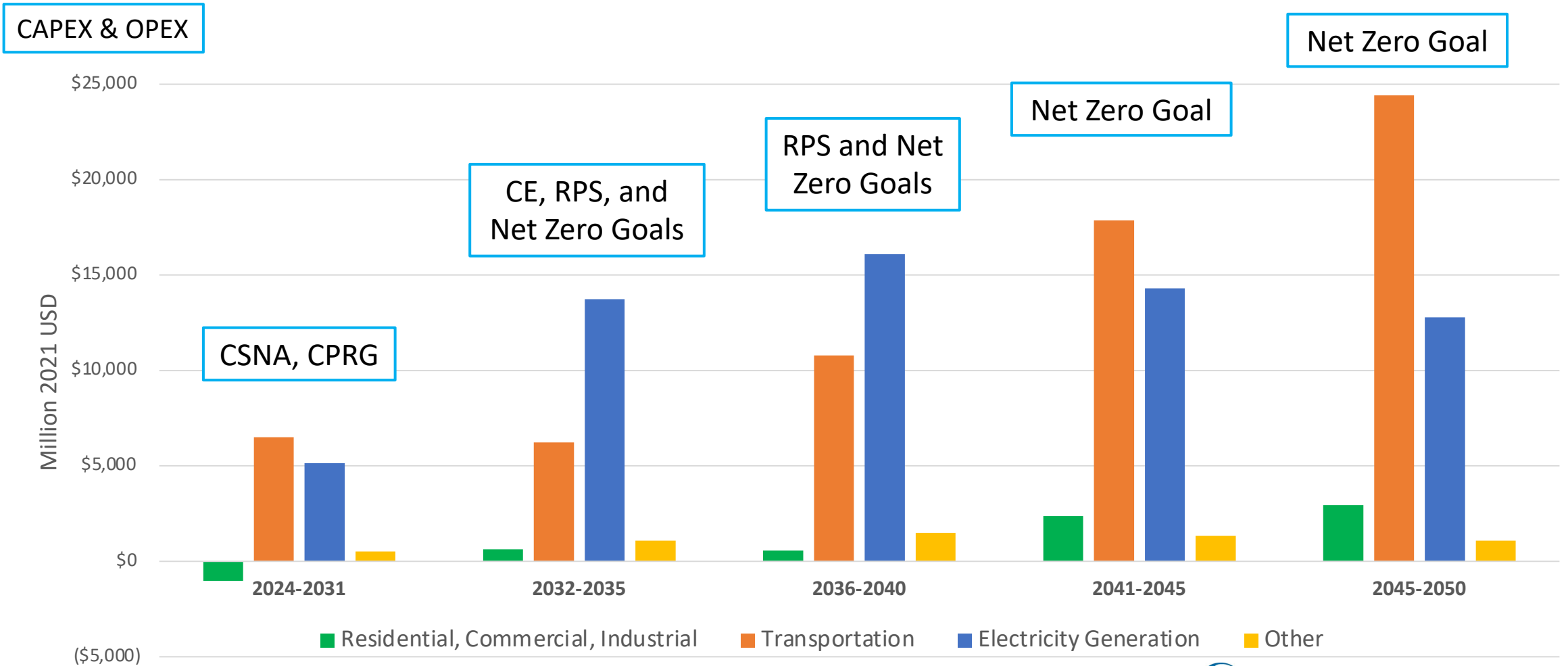


Climate actions include specific technologies, infrastructure, and practices in each sector

GHG Emissions Reductions 5 Year Periods



Investment Requirements 5-Year Periods



Energy Savings and Fuel Reductions

Annual Costs/Savings, \$millions	2024-2031	2032-2035	2036-2040	2041-2045	2045-2050
Natural Gas	(\$55)	(\$273)	(\$394)	(\$443)	(\$463)
Nuclear	\$0	\$13	\$92	\$103	\$103
Biogas	\$1	\$3	\$1	(\$1)	(\$2)
Diesel	\$16	(\$14)	(\$100)	(\$262)	(\$456)
Gasoline	(\$8)	(\$20)	(\$31)	(\$44)	(\$58)
Ethanol and Gasohol E10	(\$472)	(\$581)	(\$406)	(\$302)	(\$271)
Jet Kerosene	(\$95)	(\$168)	(\$216)	(\$284)	(\$386)
Sustainable Aviation Fuel	\$37	\$78	\$123	\$158	\$217
Electricity	\$0	(\$1)	(\$62)	(\$363)	(\$1,008)
Imported Electricity	\$250	\$692	(\$762)	(\$1,608)	(\$1,895)
Other	(\$3)	(\$18)	(\$34)	(\$49)	(\$57)
Totals	(\$328)*	(\$290)	(\$1,789)	(\$3,096)	(\$4,277)

*Annual energy savings continue over 10-20-years for each up-front investment and ultimately repay about 2/3 of these costs



Investment Requirements

CATEGORY	Estimated Investment Costs (Million 2021 USD, Undiscounted) Incremental to Current Policies ⁱ					Annual Emission (Million tCO ₂ e) Reduction				
	2024-2031	2032-2035	2036-2040	2041-2045	2045-2050	2031	2035	2040	2045	2050
	Energy Demand (Equipment/Infrastructure) ⁱⁱ	\$5,484	\$6,871	\$11,345	\$20,236	\$27,362	-6.7	-8.1	-10.4	-12.7
Residential Space Heating / Air Conditioning ⁱⁱⁱ	(\$1,169)	(\$669)	(\$1,654)	(\$609)	(\$371)	-1.0	-1.7	-2.6	-3.2	-3.4
Residential Water Heating	\$224	(\$17)	(\$336)	(\$84)	(\$123)	-0.7	-1.1	-1.3	-1.3	-1.4
Residential Cooking and Clothes Drying	(\$12)	(\$25)	(\$95)	(\$62)	(\$51)	0.0	0.0	-0.1	-0.2	-0.2
Commercial Space Heating / Air Conditioning ⁱⁱⁱ	(\$907)	(\$732)	(\$804)	(\$377)	(\$288)	-0.7	-1.3	-2.0	-2.5	-2.7
Commercial Water Heating	\$74	\$91	\$94	\$76	\$50	-0.1	-0.2	-0.3	-0.3	-0.3
Commercial Cooking	\$689	\$1,861	\$3,119	\$3,097	\$3,295	-0.1	-0.3	-0.7	-0.8	-0.9
Transportation--Additional Heavy Truck Electrification	\$163	\$324	\$489	\$660	\$745	-0.2	-0.3	-0.5	-0.8	-1.1
Transportation--EV Charging Infrastructure (Bus, Heavy Truck)	\$0	\$35	\$328	\$807	\$1,344					
Transportation--VMT reduction: Expansion of Transit	\$4,991	\$2,559	\$1,956	\$3,326	\$3,451	-2.9	-1.8	-1.2	-1.4	-2.1
Transportation--VMT reduction: E-bikes	\$1,346	\$3,321	\$8,007	\$13,063	\$18,869					
Industry--Cement Kiln Electrification and Electrical Efficiency	\$18	\$13	\$24	\$33	\$42	-0.6	-0.6	-0.6	-0.6	-0.6
Industry--Other Electrification and Efficiency	\$66	\$110	\$216	\$305	\$398	-0.3	-0.6	-0.9	-1.2	-1.5
Agriculture, Construction, Mining	\$0	\$0	\$0	\$0	\$0	-0.1	-0.2	-0.2	-0.3	-0.4
Energy Supply (Equipment/Infrastructure) ⁱⁱ	\$5,651	\$14,742	\$17,456	\$15,459	\$13,803	-2.7	-9.4	-15.2	-16.1	-15.1
Transmission and Distribution	\$322	\$877	\$1,179	\$1,011	\$898	-0.5	-0.9	-1.2	-1.4	-1.5
LNG Exports	\$38	\$0	\$0	\$0	\$0	-1.9	-1.9	-1.9	-1.9	-1.9
Rooftop Solar	\$938	\$1,191	\$1,594	\$3,169	\$3,898					
Electricity Generation--Offshore Wind	\$211	\$8,630	\$11,738	\$8,690	\$6,737					
Electricity Generation--Solar	\$1,516	\$1,427	\$1,580	\$1,448	\$1,318	0.0	-6.2	-11.6	-12.2	-11.1
Electricity Generation--Storage	\$2,495	\$2,631	\$1,928	\$1,746	\$1,566					
Electricity Generation--Avoided Fossil	(\$86)	(\$158)	(\$792)	(\$794)	(\$733)					
Electricity, Other	\$74	\$22	\$51	\$55	(\$0.6)					
Biogas Production	\$21	\$22	\$71	\$42	\$42	Emission Reductions shown under Non-Energy				
Other Energy Supply	\$124	\$99	\$107	\$92	\$78	-0.2	-0.4	-0.5	-0.5	-0.5
Non-Energy Sources	\$13	\$82	\$144	\$186	\$74	-0.8	-1.1	-2.2	-3.3	-3.9
Enteric Fermentation Mitigation	\$0	\$0	\$0	\$0	\$0	-0.1	-0.2	-0.3	-0.4	-0.4
Agricultural Soils	\$0	\$0	\$0	\$0	\$0	0.0	-0.1	-0.1	-0.1	-0.1
Manure Digesters						0.0	-0.1	-0.1	-0.2	-0.3
WWTP Biogas						-0.2	-0.5	-0.8	-1.4	-1.4
Composting and Increased Landfill Gas Control	\$13	\$8	\$29	\$0	\$0	-0.4	-0.2	0.0	0.0	-0.1
Cement Clinker Substitution and CCS	\$0	\$73	\$115	\$186	\$74	-0.2	-0.5	-0.8	-1.1	-1.6
OVERALL ESTIMATED TOTAL	\$11,148	\$21,694	\$28,944	\$35,881	\$41,239	-10.2	-18.9	-27.8	-32.0	-33.6

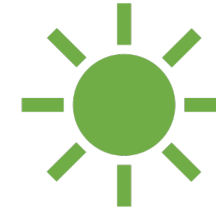
Energy Supply



Findings

Renewables key to climate goals

Timely implementation depends on cooperation



Actions

Utility Solar Expansion

Expanded Offshore Wind

Calvert Cliffs Life Extension

RGGI Net Zero Generation 2040

Rooftop Solar Expansion

Expanded Electricity Storage

Natural Gas Generation Retired

Retirement of Waste to Energy (WTE) Generation

Liquefied Natural Gas (LNG)

Liquefaction Electrification

Buildings, Facilities, Industry



Findings

Climate goals won't be met without demand-side changes

Changes must be applied to millions of buildings,

Sources of funding need definition

Industrial actions needed, but provide less GHG reductions



Actions

Low Income (LI) Electrification

All Electric Building Code Expansion

Building Energy Performance Standards (BEPS)

EmPOWER Restructuring

Zero NOx Appliance Standards

Cement Sector Electrification

Cement Clinker Substitution

Industrial Energy Efficiency and Electrification

Transportation



Findings

Transportation rivals energy supply and buildings

Electrification policies provide significant reductions

Must augment and match with fueling and infrastructure

Electrification makes VMT reduction complex

Cooperation with public and private sector actors needed



Actions

Vehicle Miles Traveled (VMT) Reduction

Additional HDV, Bus, and Heavy Equipment Electrification

Rail Electrification

Freight Mode Shift and Rail Freight Electrification

Other Transportation Electrification

Air Transport Improvements

Sustainable Aviation Fuel

Non-Energy



Findings

Non-energy actions are also needed to meet goals

Provide generally less GHG reduction than other sectors

Methane's high GWP (20-year) is important

Some actions may be relatively easy to implement

Some may be difficult or may be resisted



Actions

Methane Capture from Landfills

Expanded Composting

Biogas Production and Use

Enteric Methane Mitigation

Biofertilizer

Soil Management Program

2031 and Long-Term Net Zero Goals

GHG cuts from BAU Current Policies will be well short of goals

Additional Actions cut 2031 GHGs over 10 MMtCO₂e; 55% from 2006

Leaves a gap of about 6 MMtCO₂e for 2031 goal but meets it by 2033

Additional Actions fall short of net zero by 2045; gross GHGs drop from 87 MMtCO₂e in 2023 to 15 MMtCO₂e by 2050

After subtracting carbon sinks of 8 MMtCO₂e from forests, soils, and landfills, net GHGs reach about 7 MMtCO₂e by 2050

2031 and Net Zero goals require all sectors to act

2035, 2040 Clean Energy Goals

With Additional Actions, renewable generation reaches 68% of electricity output by 2040, with 17% being nuclear generation and the remaining 15% from PJM imports

If RGGI states accomplish clean generation goals by 2040, Maryland's electricity is entirely clean energy sourced

By 2035, about 3% of Maryland's in-state generation comes from fossil fuel and the level of state electricity from clean energy depends on whether PJM imports are carbon-free

CO₂e per MWh to generate the power imported to Maryland will fall by two-thirds from Additional Actions, leaving the state at above 90% clean energy for 2035

Investment Requirements

Implementation of GHG emissions reduction actions results in annual net costs of \$38 million in 2024-2031, then \$2.4 billion in 2045-2050

Overall costs of Additional Actions are offset if a social cost of carbon in \$190 per tCO₂e is applied; benefit of over \$4 billion by 2045

Up front investments are \$11 billion for 2024-2031. Additional increments of \$22 billion to 2035 (4 years), \$29 billion to 2040 (5 years), and \$36 billion to 2045 (5 years), and \$41 to 2050 (5 years)

Two thirds of annualized costs from 2024-2050 are expected to be offset by avoidance of expenditures on fossil fuels, creating major end use savings for energy consumers and significant payback capability for financing

Investments enable Maryland consumers to avoid major expenses for fossil fuels, reduce local air pollution, and increase job creation

Long-term investments in climate stabilization actions are generational; benefit streams continue for 20 years or more. Benefits from much of the upfront investments in the 2024-31 period extend past 2050

Overall investment requirements for climate stabilization and clean energy goals in Maryland are very consistent in scale with UNFCCC estimates of global investment needed to meet goals of the Paris Agreement and mid-century temperature stabilization goals

Modeling Platform



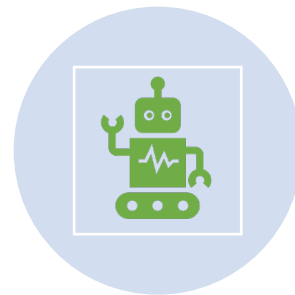
Models and database provide a detailed, comprehensive identification and multi-metric assessment of end uses of funds



Support implementation of technologies, practices, and infrastructure in all sectors



Support low income and disadvantaged communities, mobilization of investment, blended finance, emerging issues, monitoring



Start from a comprehensive statewide perspective of GHG emissions and their sources

Discussion

Goals

Policies

Budgets

Financing

Capacities

Assessments

Consensus
building

Cooperation

Thank You!

Tom Peterson

tpeterson@climatestrategies.us

David Von Hippel

dvonhip@igc.org

Holly Lindquist

hlindquist@climatestrategies.us

Arianna Ugliano

augliano@climatestrategies.us

Michael Larson

mlarson@climatestrategies.us