



Analysis of Cap and Trade among Power Sectors of RGGI states and Carbon Tax in Maryland Non-C&T Sectors

A. Free Allocation of Allowances

The Non-linear Programming (NLP) Model we used in the study is capable of analyzing various environmental policy instruments, including cap & trade, carbon taxes, and regulations, under a variety of conditions. For cap & trade, for example, the latter includes: free granting vs. auctioning, upper limits on permit prices, offsets, banking, etc.

Because of the extensive availability of low-cost mitigation options, in some cases the supply of allowances in a cap & trade (C&T) would exceed the demand for allowances at all positive allowance prices. Hence, trading would not be possible (we cannot obtain a feasible solution for a positive allowance price from our model that equalizes supply and demand of allowances in the market). Instead, we analyze two scenarios with different assumptions for allowance price levels that resolve this problem. We then evaluate the supply and demand of allowances from each state, and the costs/savings of individual states before and after entering the C&T system.

Example scenario: Marginal Cost (MC) = Allowance Price = \$7/tCO₂

1. According to the initial RGGI allowance allocation, ME, NH, VT, and RI do not have any GHG mitigation targets, since the allocated allowances to these states (see Column 3 of Table 1) exceed their 2020 BAU emission levels (see Column 2 of Table 1). For the remaining 6 states, which have binding mitigation goals, the reduction target (%) is computed in Column 4 of Table 1. Next, we calculate the reduction potential level in percentage terms at MC=\$7 (see Column 3 of Table 2). If this percentage is lower than the one shown in Column 4 in Table 1, the state would be a buyer of allowances. As shown in Column 4 of Table 2, CT and NJ would be the buyers. In total, the allowances demand from these two states is 5.36 MMtCO₂. The allowance selling states would be DE, MD, ME, NH, NY, VT, MA, and RI.
2. After achieving its own reduction target (41.94% below 2020 BAU level), the total allowances available for DE to sell with mitigation cost less than \$7 are 0.23 MMtCO₂. We assume the remaining RGGI allowance demand (5.36-0.23=5.13 MMtCO₂) would be provided by the other 7 allowance selling states evenly, i.e., each of the selling states would sell 5.13/7=0.73 MMtCO₂ in the market.
3. MD, NY, and MA do not have over-allocated allowances to sell. Therefore, they will provide all of the 0.73 MMtCO₂ allowances by autarkic (their own) mitigation actions with costs less than \$7/tCO₂ (after achieving their own state mitigation targets, these three states still have the capability to reduce emissions with cost less than \$7/tCO₂). ME, NH, RI, and VT will decide how much of the allowances they sell would come from autarkic mitigation actions and how much would come from the excess allowances they possess. To gain the largest profit, these four states would choose to utilize all the cost-saving mitigation potentials inside the state first, since

selling these allowances would bring them not only the cost-savings associated with the implementation of the mitigation options, but also the revenues from selling the allowances at the price of \$7/tCO₂. After exhausting cost-saving mitigation potentials, they will next choose to sell the excess allowances they hold. They can sell these allowances without incurring any mitigation cost. After using up the excess allowances, these three states would be willing to sell those allowances they can achieve through autarkic mitigation actions with costs less than \$7/tCO₂.

The simulation results of the scenario with allowance price equal to \$7/tCO₂ are shown in Table 3. Simulation results of the scenario that assumes allowance price to be \$1/tCO₂ are presented in Table 4. In this case, DE would be the third buyer besides CT and NJ, since the state autarkic mitigation potentials with marginal cost less than \$1 fall short of meeting the state target (though DE's demand of allowance is very small (0.06 MMtCO₂e) compared with the other two buyers CT and NJ). We also did similar simulations with assumptions of allowance price at \$3/tCO₂ and \$5/tCO₂. These two cases yield similar simulation results as the \$7 case, with only CT and NJ as the buyers. From the three cases with price at the levels of \$3, \$5, and \$7, the results show that there is a negative relationship between the level of allowance price and the amount of allowances traded among the states. Approximately, allowance transactions are reduced 11 thousand tCO₂ with each increased dollar in the allowance price.

Table 1. RGGI States 2020 Emission Projections and Caps

| | 2020 BAU Emissions (MMtCO ₂) | Cap/Budget (MMtCO ₂) | Reduction Target (%) | Allowance beyond BAU (MMtCO ₂) | Reduction Target (MMtCO ₂) |
|-------|--|----------------------------------|----------------------|--|--|
| CT | 13.26 | 9.09 | 31.45% | 0.00 | 4.17 |
| DE | 11.07 | 6.43 | 41.94% | 0.00 | 4.65 |
| MD | 38.83 | 31.88 | 17.90% | 0.00 | 6.95 |
| ME | 1.90 | 5.06 | 0.00% | 3.15 | -3.15 |
| NH | 4.93 | 7.33 | 0.00% | 2.40 | -2.40 |
| NJ | 23.40 | 19.46 | 16.86% | 0.00 | 3.95 |
| NY | 56.11 | 54.66 | 2.58% | 0.00 | 1.45 |
| VT | 0.03 | 1.04 | 0.00% | 1.01 | -1.01 |
| MA | 24.97 | 22.66 | 9.26% | 0.00 | 2.31 |
| RI | 1.78 | 2.26 | 0.00% | 0.48 | -0.48 |
| | | | | | |
| Total | 176.30 | 159.87 | 9.32% | 7.04 | 16.43 |

* The shaded states, ME, NH, VT, and RI, have allocated allowances higher than their projected 2020 BAU emission levels. As a result, these states have zero emission reduction targets in their power sector. In addition, they can sell the excess allowances in the market at zero mitigation cost.

Sources: 1. RGGI States GHG Caps by Year from 2009 to 2018 are provided by Jeff Wennberg from CCS.

Numbers for year 2019 and year 2020 are estimated by extrapolating 2014 to 2018 numbers.

2. RGGI states 2020 BAU emission projections are obtained from RGGI website <http://www.rggi.org/documents.htm>, the Reference Case projections. The 2020 values are computed by interpolating 2018 and 2021 projections.

Table 2. Determination of Allowances Purchasing and Selling States

| | Reduction Target (%) | In-state Reduction Potential with MC ≤ \$7 (%) | Whether an Allowance Buyer | Amount of Allowances to Buy |
|-------|----------------------|--|----------------------------|-----------------------------|
| CT | 31.45% | 5.78% | Yes | 3.40 |
| DE | 41.94% | 44.05% | No | |
| MD | 17.90% | 42.90% | No | |
| ME | 0.00% | 39.92% | No | |
| NH | 0.00% | 6.78% | No | |
| NJ | 16.86% | 8.49% | Yes | 1.96 |
| NY | 2.58% | 5.44% | No | |
| VT | 0.00% | 100.00% | No | |
| MA | 9.26% | 47.72% | No | |
| RI | 0.00% | 62.95% | No | |
| | | | | |
| Total | 9.32% | 23.54% | — | 5.36 |

Note: If the percentage in the third column is less than the reduction target in percentage terms in the second column, the state would be an allowance buyer.

Table 3. Power Sector Cap and Trade Simulation among 10 RGGI States in Year 2020

Scenario 1: Allowance Price = \$7/tCO₂

(million dollars or otherwise specified)

| State | Before Trading | After Trading | | | Cost Saving | Allowances Traded | Emission Reduction w/ Trading | | Emission Reduction Goal |
|-------|-----------------|-----------------|--------------|-----------|-------------|-----------------------------|-------------------------------|--------------------|-------------------------|
| | Mitigation Cost | Mitigation Cost | Trading Cost | Net Cost | | (million tCO ₂) | (million tCO ₂) | (percent from BAU) | (percent from BAU) |
| CT | 1,200.05 | -49.64 | 23.83 | -25.81 | 1,225.86 | 3.40 | 0.77 | 5.78 | 31.45 |
| DE | -171.89 | -170.83 | -1.61 | -172.43 | 0.55 | -0.23 | 4.88 | 44.05 | 41.94 |
| MD | -407.91 | -439.20 | -5.13 | -444.33 | 36.43 | -0.73 | 7.68 | 19.79 | 17.90 |
| ME | 0.00 | -41.49 | -5.13 | -46.62 | 46.62 | -0.73 | 0.72 | 38.00 | 0.00 |
| NH | 0.00 | -25.72 | -5.13 | -30.85 | 30.85 | -0.73 | 0.32 | 6.50 | 0.00 |
| NJ | 38.45 | -313.93 | 13.71 | -300.22 | 338.67 | 1.96 | 1.99 | 8.49 | 16.86 |
| NY | -418.66 | -530.22 | -5.13 | -535.36 | 116.70 | -0.73 | 2.18 | 3.89 | 2.58 |
| VT | 0.00 | -2.34 | -5.13 | -7.48 | 7.48 | -0.73 | 0.03 | 100.00 | 0.00 |
| MA | -235.68 | -301.68 | -5.13 | -306.81 | 71.13 | -0.73 | 3.05 | 12.20 | 9.26 |
| RI | 0.00 | -61.48 | -5.13 | -66.61 | 66.61 | -0.73 | 1.07 | 60.45 | 0.00 |
| Total | 4.37 | -1,936.53 | 0.00 | -1,936.53 | 1,940.89 | 5.36 ^a | 22.69 | 12.87 | 13.31 |

^a Represents number of allowances bought or sold.

Table 4. Power Sector Cap and Trade Simulation among 10 RGGI States in Year 2020

Scenario 2: Allowance Price = \$1/tCO₂

(million dollars or otherwise specified)

| State | Before Trading | After Trading | | | Cost Saving | Allowances Traded | Emission Reduction w/ Trading | | Emission Reduction Goal |
|-------|-----------------|-----------------|--------------|-----------|-------------|-----------------------------|-------------------------------|--------------------|-------------------------|
| | Mitigation Cost | Mitigation Cost | Trading Cost | Net Cost | | (million tCO ₂) | (million tCO ₂) | (percent from BAU) | (percent from BAU) |
| CT | 1,200.05 | -49.77 | 3.44 | -46.33 | 1,246.38 | 3.44 | 0.73 | 5.54 | 31.45 |
| DE | -171.89 | -171.97 | 0.06 | -171.91 | 0.03 | 0.06 | 4.59 | 41.45 | 41.94 |
| MD | -407.91 | -441.27 | -0.78 | -442.06 | 34.15 | -0.78 | 7.73 | 19.92 | 17.90 |
| ME | 0.00 | -41.49 | -0.78 | -42.27 | 42.27 | -0.78 | 0.72 | 38.00 | 0.00 |
| NH | 0.00 | -25.72 | -0.78 | -26.50 | 26.50 | -0.78 | 0.32 | 6.50 | 0.00 |
| NJ | 38.45 | -314.07 | 1.99 | -312.07 | 350.52 | 1.99 | 1.95 | 8.34 | 16.86 |
| NY | -418.66 | -535.40 | -0.78 | -536.18 | 117.52 | -0.78 | 2.23 | 3.98 | 2.58 |
| VT | 0.00 | -2.34 | -0.78 | -3.13 | 3.13 | -0.78 | 0.03 | 100.00 | 0.00 |
| MA | -235.68 | -306.07 | -0.78 | -306.85 | 71.17 | -0.78 | 3.10 | 12.40 | 9.26 |
| RI | 0.00 | -61.48 | -0.78 | -62.26 | 62.26 | -0.78 | 1.07 | 60.45 | 0.00 |
| Total | 4.37 | -1,949.58 | 0.00 | -1,949.58 | 1,953.94 | 5.49 ^a | 22.49 | 12.76 | 13.31 |

^a Represents number of allowances bought or sold.

B. Auction of Allowances

In the case where allowances are auctioned, we assume the 2020 emission caps for CT, DE, MD, NJ, NY, and MA are the same as in the free granting case. For ME, NH, VT, and RI, which have excess allowances in the free granting case, we assume their caps in the auction case would equal the state BAU 2020 emission levels (i.e., there is no reason to purchase any excess allowances at auction). Table 5 shows the emission caps for the 10 RGGI states in the auction case.

Table 5. RGGI States 2020 Emission Projections and Caps (Auction Case)

| | 2020 BAU Emissions (MMtCO ₂) | Cap/Budget (MMtCO ₂) |
|-------|--|----------------------------------|
| CT | 13.26 | 9.09 |
| DE | 1.07 | 6.43 |
| MD | 8.83 | 31.88 |
| ME | 1.90 | 1.90 |
| NH | 4.93 | 4.93 |
| NJ | 23.40 | 19.46 |
| NY | 56.11 | 54.66 |
| VT | 0.03 | 0.03 |
| MA | 24.97 | 22.66 |
| RI | 1.78 | 1.78 |
| | | |
| Total | 176.30 | 152.82 |

In the auction case, there would be no trading among states. According to the Coase Theorem, in equilibrium, each state would choose to mitigate emissions as long as its marginal abatement cost is lower than or equal to the price of allowances, and purchase the remaining allowance (the difference between the state's BAU level and the amount mitigated by autarkic actions) from the auctioneer. Table 6 presents the amount of emissions that can be reduced by each state's autarkic mitigation actions associated with marginal cost of \$7/tCO₂e. The simulation results of the auction case with allowance price equal to \$7/tCO₂e are presented in Table 7. A second simulation with the auction price assumed to be at \$1/tCO₂e is presented in Table 8.

In usual C&T cases, where the equilibrium point corresponds to a positive allowance price, auction and free granting would reach the same cost-effectiveness level, i.e., the auction price would be at the same level as the equilibrium price in the allowance trading market, and the collaborative CO₂ reductions achieved by the partner states in these two allocation cases would be the same and equal to the overall emission reduction target of the region. The only difference between these two allocation cases would be that the auction can generate revenues to the state government, which in turn can be recycled to fund R&D in clean energy technologies, end-use energy efficiencies, etc., and thus lower the impacts to the electricity ratepayers.

However, as indicated in Section A, the supply of allowances would exceed the demand for allowances at all positive allowance prices in RGGI's case. Therefore, in the case of C&T with a grandfathering allocation strategy and with the assumed market price at \$7/tCO₂, to ensure the balance of trade in the market (supply equalizing demand), many states such as MD, NY, and MA would not use up all their mitigation potentials with marginal cost less than \$7/tCO₂. Collaboratively, the emission reductions achieved by the 10 states in the free granting case with allowance price equal to \$7/tCO₂ are 22.69 MMtCO₂. In the auction case, each state would utilize all its mitigation potential with marginal cost less than \$7/tCO₂ before purchasing allowances from the auctioneer. As a result, the total emission reductions achieved by the 10 states in this case are 41.50 MMtCO₂. Since considerable amounts of un-used mitigation potentials of some states such as MD and MA in the free granting case are associated with cost savings, the total cost savings of mitigation in the auction case (2.53 billion) are higher than the total mitigation cost savings in the free granting case (1.94 billion). In addition, in the auction case, many states would reduce more emissions than required by the state mitigation target. The additional reductions achieved by these states can be saved for future use.

Comparing the two auction cases with auction prices at \$7 and \$1, the amount the states choose to reduce by mitigation options (41.50 MMtCO₂ vs. 39.62 MMtCO₂) and the amount to be bought from the auctioneer (134.79 MMtCO₂ vs. 136.68 MMtCO₂) differ slightly. The big difference in total auction cost between these two cases is due primarily to the difference of the two auction price levels.

Table 6. Mitigation Potential Associated with MC=\$7/tCO₂e

| | Cap/Budget (MMtCO ₂) | In-state Reduction Potential with MC≤ \$7 (%) | In-state Reduction Potential with MC≤ \$7 (MMtCO ₂) |
|-------|-------------------------------------|---|---|
| CT | 9.09 | 5.78% | 0.77 |
| DE | 6.43 | 44.05% | 4.88 |
| MD | 31.88 | 42.90% | 16.66 |
| ME | 1.90 | 39.92% | 0.76 |
| NH | 4.93 | 6.78% | 0.33 |
| NJ | 19.46 | 8.49% | 1.99 |
| NY | 54.66 | 5.44% | 3.05 |
| VT | 0.03 | 100.00% | 0.03 |
| MA | 22.66 | 47.72% | 11.92 |
| RI | 1.78 | 62.95% | 1.12 |
| | | | |
| Total | 152.82 | 23.54% | 41.50 |

Table 7. Simulation Results of an Auction Case among RGGI States (with assumed auction price at \$7/tCO₂)

| State | Total BAU Emissions in 2020 (million tCO ₂) | 2020 Emissions Cap/Budget (million tCO ₂) | Emission Reduction Undertaken by the State ^a | | Mitigation Cost (million dollars) | Emission Allowances Bought from Auctioneer (million tCO ₂) | Auction Cost (million dollars) ^b | Net Cost (million dollars) ^c |
|-------|---|---|--|--------------------------------|--|---|--|---|
| | | | (percent from BAU) | (million tCO ₂) | | | | |
| CT | 13.26 | 9.09 | 5.78 | 0.77 | -49.64 | 12.50 | 87.47 | 37.83 |
| DE | 11.07 | 6.43 | 44.05 | 4.88 | -170.83 | 6.20 | 43.37 | -127.45 |
| MD | 38.83 | 31.88 | 42.90 | 16.66 | -604.01 | 22.17 | 155.20 | -448.81 |
| ME | 1.90 | 1.90 | 39.92 | 0.76 | -41.36 | 1.14 | 8.00 | -33.36 |
| NH | 4.93 | 4.93 | 6.78 | 0.33 | -25.67 | 4.59 | 32.16 | 6.48 |
| NJ | 23.40 | 19.46 | 8.49 | 1.99 | -313.93 | 21.42 | 149.92 | -164.01 |
| NY | 56.11 | 54.66 | 5.44 | 3.05 | -573.12 | 53.06 | 371.43 | -201.69 |
| VT | 0.03 | 0.03 | 100.00 | 0.03 | -2.34 | 0.00 | 0.00 | -2.34 |
| MA | 24.97 | 22.66 | 47.72 | 11.92 | -692.28 | 13.06 | 91.40 | -600.88 |
| RI | 1.78 | 1.78 | 62.95 | 1.12 | -61.32 | 0.66 | 4.61 | -56.71 |
| Total | 176.30 | 152.82 | 23.54 | 41.50 | -2,534.51 | 134.79 | 943.56 | -1,590.95 |

^a In equilibrium, each state will choose to mitigate to the level that its marginal abatement cost equals the auction price.

^b We assume the auction price is \$7/tCO₂ in this case.

^c Sum of Mitigation Cost and Auction Cost.

Table 8. Simulation Results of an Auction Case among RGGI States (with assumed auction price at \$1/tCO₂)

| State | Total BAU Emissions in 2020 (million tCO ₂) | 2020 Emissions Cap/Budget (million tCO ₂) | Emission Reduction Undertaken by the State ^a | | Mitigation Cost (million dollars) | Emission Allowances Bought from Auctioneer (million tCO ₂) | Auction Cost (million dollars) ^b | Net Cost (million dollars) ^c |
|-------|---|---|---|-----------------------------|-----------------------------------|--|---|---|
| | | | (percent from BAU) | (million tCO ₂) | | | | |
| CT | 13.26 | 9.09 | 5.54 | 0.73 | -49.77 | 12.53 | 12.53 | -37.24 |
| DE | 11.07 | 6.43 | 41.45 | 4.59 | -171.97 | 6.48 | 6.48 | -165.49 |
| MD | 38.83 | 31.88 | 40.42 | 15.70 | -607.83 | 23.13 | 23.13 | -584.70 |
| ME | 1.90 | 1.90 | 38.28 | 0.73 | -41.49 | 1.17 | 1.17 | -40.31 |
| NH | 4.93 | 4.93 | 6.54 | 0.32 | -25.72 | 4.61 | 4.61 | -21.11 |
| NJ | 23.40 | 19.46 | 8.34 | 1.95 | -314.07 | 21.45 | 21.45 | -292.62 |
| NY | 56.11 | 54.66 | 5.35 | 3.00 | -573.31 | 53.11 | 53.11 | -520.20 |
| VT | 0.03 | 0.03 | 100.00 | 0.03 | -2.34 | 0.00 | 0.00 | -2.34 |
| MA | 24.97 | 22.66 | 45.96 | 11.48 | -694.03 | 13.50 | 13.50 | -680.54 |
| RI | 1.78 | 1.78 | 60.81 | 1.08 | -61.47 | 0.70 | 0.70 | -60.78 |
| Total | 176.30 | 152.82 | 22.47 | 39.62 | -2,542.01 | 136.68 | 136.68 | -2,405.33 |

^a In equilibrium, each state will choose to mitigate to the level that its marginal abatement cost equals the auction price.

^b We assume the auction price is \$1/tCO₂ in this case.

^c Sum of Mitigation Cost and Auction Cost.

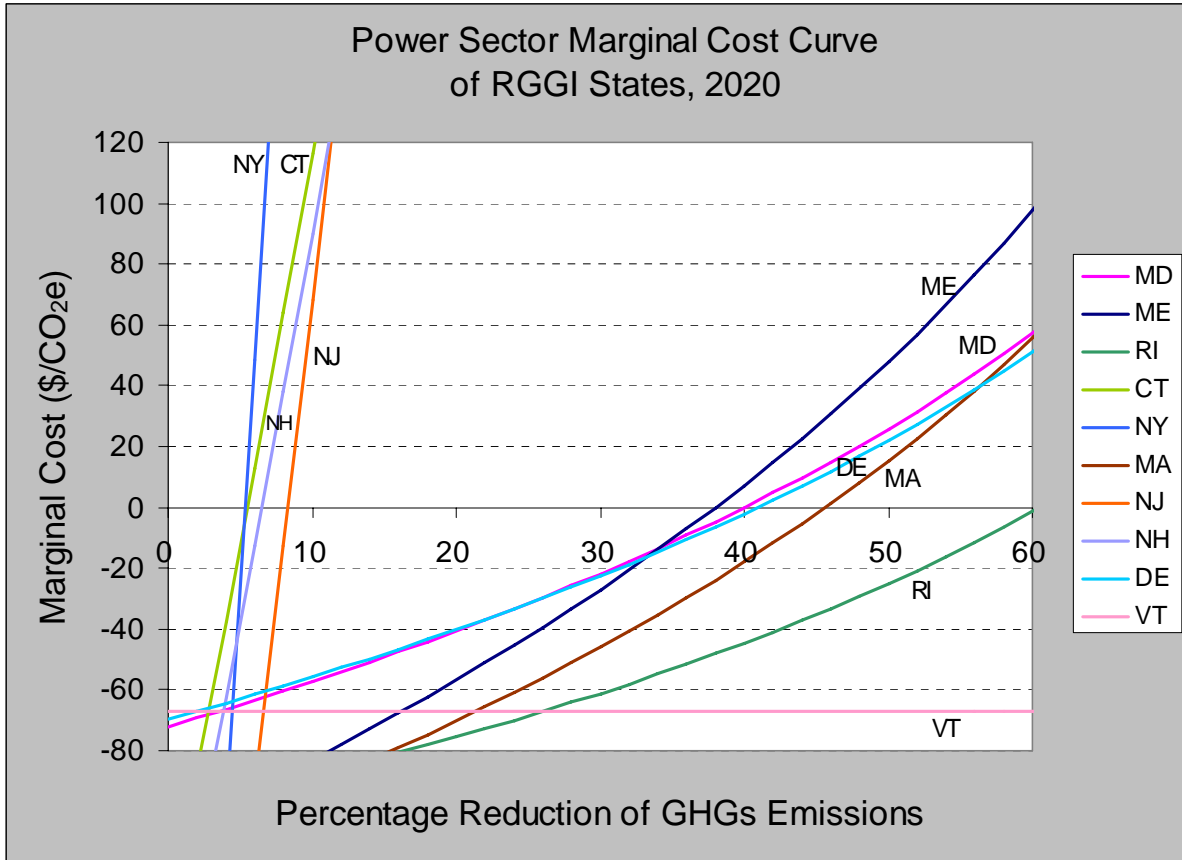


Figure 1. State Marginal Cost Curves of Power Sector, 2020

Notes: 1. There are no direct data for MA, NJ, NH, and DE. Marginal cost curves for these four states are developed based on cost curves of RI, NY, CT, and MD, respectively.

2. The marginal cost curves of the states are developed based on the reduction potential and mitigation cost/saving data of individual options that contribute to the emission reductions from power sector. These options not only include those designed directly for the electricity supply sector (such as promotion of renewable energy utilization, repowering existing plants, generation performance standards, etc.), but also include options in RCI sectors that contribute to the reduction of electricity consumption (e.g., demand-side management, energy efficiency appliances, building codes, etc.). The emission reduction potentials of these options are adjusted by multiplying the percentage of electricity consumption to total energy consumption in the RCI sector. RCI options that relate entirely to reduction of other fossil fuels consumption (such as gas, oil) are not included in the cost curves above.

Sources:

1. Connecticut Governor's Steering Committee on Climate Change. 2005. *2005 CT Climate Change Action Plan*. <http://www.ctclimatechange.com/StateActionPlan.html>.
2. Maryland Commission on Climate Change. 2008. *Draft Straw Proposals of Policy Options*. http://www.mdclimatechange.us/GHG_Carbon_Mitigation_WG.cfm.
3. Maine Department of Environmental Protection. 2004. *Final Maine Climate Action Plan 2004*. <http://www.maine.gov/dep/air/greenhouse/>.
4. Center for Clean Air Policy and New York GHG Task Force. 2003. *Recommendations to Governor Pataki for Reducing New York State Greenhouse Gas Emissions*. http://www.ccap.org/pdf/04-2003_NYGHG_Recommendations.pdf

5. Rhode Island Greenhouse Gas Process. 2002. *Rhode Island Greenhouse Gas Action Plan*.

<http://rihg.raabassociates.org/>.

6. Vermont Governor's Commission on Climate Change. 2007. *Final Report and Recommendations of the*

Governor's Commission on Climate Change. <http://www.anr.state.vt.us/air/Planning/htm/ClimateChange.htm>.

C. Carbon Tax

In this simulation, we will estimate the level of carbon tax to the non-C&T sectors to yield the Maryland state reduction target in year 2020 — 25% below 2006 levels.

Table 9. Emission Reduction Target by Sector to Achieve the Maryland State Goal

| | 2006 (MMtCO ₂) | 2020 (MMtCO ₂) | Emission Cap in 2020 (25% below 2006) (MMtCO ₂) | Emission Reduction Target | |
|--|-------------------------------|-------------------------------|--|---------------------------|------------|
| | | | | (MMtCO ₂) | Percentage |
| Emissions from Electricity —Production Based | 28.2 | 38.8 | 21.2 | 17.7 | 45.5% |
| Emissions from Electricity —Consumption Based | 43.3 | 52.8 | 32.5 | 20.3 | 38.4% |
| Emissions from Non- electricity Sector | 63.4 | 76.9 | 47.6 | 29.4 | 38.2% |
| Total Gross Emissions (Consumption Based) | 106.8 | 129.7 | 80.1 | 49.6 | 38.3% |

According to the analyses in Sections A and B, the Power Sector in Maryland can reach the state mitigation goal by implementing in-state policies and measures affecting the power sector and by purchasing allowances from the RGGI C&T system. The power sector would implement in-state mitigation options as long as the marginal abatement cost is less than or equal to the price of the allowance, and purchase the remaining allowances from power sector in other states (in the free granting case) or the auctioneer (in the auction case).

Next, we need to look at the mitigation options list of the non-C&T sectors in Maryland in order to evaluate:

- A. whether the contributions of mitigation options from all the non-C&T sectors would meet the state goal and,
- B. if not, what would be the carbon tax level to non-C&T sectors to achieve the goal;
- C. if the mitigation options meet the state goal, how many incremental tons of CO₂ will be abated for each increasing \$ of carbon tax.

Table 10 shows the options list of non-C&T sectors in Maryland. Note that some RCI sector options that entirely or partially contribute to electricity consumption reduction are included in the options list to develop the MD power sector mitigation cost curve in Figure 1. To avoid double-counting, the part of emission mitigation potentials related to electricity consumption reduction of those options are not included in the list in Table 10. Please also note that only options with quantified reduction potentials and costs/savings estimated by the TWGs are included in Table 10. Column 3 of the table presents the estimated 2020 annual GHG reduction potential for each option, with reduction potentials translated into percentages of the 2020 BAU emissions level in Column 5. The estimated cost or cost saving per ton of GHG removed by each option in 2020 is presented in Column 4. The options are ordered in ascending sequence in terms of cost, beginning with the cheapest option. Column 6 calculates the cumulative GHG

reduction potentials of the first n policy options listed in the table. The last column presents the proportion of GHG mitigation contributed by each option.

Table 10. Mitigation Options List of Non-C&T Sectors in Maryland

| Sector | Climate Mitigation Actions | Estimated 2020 Annual GHG Reduction Potential (MMtCO ₂ e) | Estimated Cost or Cost Savings per ton GHG Removed | GHG Reduction Potential as Percentage of 2020 Baseline Emissions ¹ | Cumulative GHG Reduction Potential | Weights (add-up to 100) |
|--------------------|--|--|--|---|------------------------------------|-------------------------|
| TLU-3 | Transit | 2.80 | -\$917.00 | 3.64% | 3.64% | 5.39 |
| TLU-9 ² | Commuter Choice and other Pricing Measures | 2.20 | -\$322.00 | 2.86% | 6.50% | 4.24 |
| AFW-2 | Managing Urban Trees and Forests for Greenhouse Gas Benefits (With Mitigation of Forest Loss Due to Insects, Disease, Pests, and Invasive Species) | 1.90 | -\$251.00 | 2.47% | 8.97% | 3.66 |
| AFW-5 | “Buy Local” Programs for Sustainable Agriculture, Wood, and Wood Products—a. Farmer’s Market | 0.03 | -\$167.00 | 0.04% | 9.01% | 0.06 |
| RCI -4 | Improved design, construction, appliances, and lighting in new and existing state and local government buildings, “Government Lead-by-example” | 0.44 | -\$60.00 | 0.58% | 9.59% | 0.85 |
| RCI -7 | More Stringent Appliance/Equipment Efficiency Standards (<i>state-level, or advocate for regional or federal-level standards</i>) | 0.06 | -\$54.00 | 0.08% | 9.67% | 0.13 |
| RCI -10 | Energy Efficiency Resource Standard (EERS) | 3.83 | -\$52.00 | 4.98% | 14.65% | 7.38 |
| RCI -1 | Improved Building and Trade Codes and Beyond-Code Building Design and Construction | 0.73 | -\$39.00 | 0.95% | 15.61% | 1.41 |
| AFW-8 | Nutrient Trading With Carbon Benefits | 0.14 | -\$30.00 | 0.18% | 15.79% | 0.27 |
| AFW-9 | Waste Management Through Source Reduction and Advanced Recycling | 29.20 | -\$6.00 | 37.96% | 53.75% | 56.26 |
| AFW-6 | Expanded Use of Forest and Farm Feedstocks and By-Products for Energy Production--Methane Utilization From Livestock Manure and Poultry Litter | 0.04 | \$0.20 | 0.05% | 53.80% | 0.08 |
| AFW-7 | In-State Liquid Biofuels Production-Biodiesel | 0.18 | \$7.00 | 0.23% | 54.04% | 0.35 |

| | | | | | | |
|---------------------|--|------|----------|-------|--------|------|
| AFW-6 | Expanded Use of Forest and Farm Feedstocks and By-Products for Energy Production—Biomass (Inc. Ag. Residue, Forest Feedstocks, and Energy Crops) | 0.50 | \$12.00 | 0.65% | 54.69% | 0.96 |
| AFW-3 | Afforestation, Reforestation, and Restoration of Forests and Wetlands--a. Afforestation | 0.60 | \$29.00 | 0.78% | 55.47% | 1.16 |
| AFW-4 | Forested Land--b. Forested land | 2.70 | \$37.00 | 3.51% | 58.98% | 5.20 |
| AFW-3 | Afforestation, Reforestation, and Restoration of Forests and Wetlands--b. Riparian areas | 0.10 | \$44.00 | 0.13% | 59.11% | 0.19 |
| TLU-4 ² | Low Greenhouse Gas Fuel Standard | 1.90 | \$60.00 | 2.47% | 61.58% | 3.66 |
| AFW-7 | In-State Liquid Biofuels Production-Ethanol | 0.91 | \$80.00 | 1.18% | 62.76% | 1.75 |
| AFW-4 | Forested Land--a. Agricultural Land | 0.28 | \$87.00 | 0.36% | 63.12% | 0.54 |
| RCI -8 | Rate structures and Technologies to Promote Reduced GHG Emissions (including inverted block rates) | 0.06 | \$115.00 | 0.08% | 63.20% | 0.12 |
| AFW-1 | Forest Management for Enhanced Carbon Sequestration (With Mitigation of Forest Loss Due to Insects, Disease, Pests, and Invasive Species) | 0.09 | \$135.00 | 0.12% | 63.32% | 0.17 |
| TLU-10 ² | Transportation Technologies | 3.20 | \$650.00 | 4.16% | 67.48% | 6.17 |

¹ 2020 projected gross CO₂ emissions from non-C&T sectors are 76.92 MMtCO₂e.

² Numbers presented in the column of “Estimated Cost or Cost Savings per ton GHG Removed” are the average of the high and low estimates by the TLU TWG.

From Column 6 of Table 10, we see that the cumulative mitigation potential of options with cost savings is around 53.7% of the non-C&T sectors’ 2020 BAU emissions level. As shown in Table 9, the reduction goal of 25% below the 2006 level translates to 38.2% below 2020 BAU level for the non-C&T sectors. Therefore, the state goal can be over-achieved by implementing only the cost-saving mitigation options.

Thus, to achieve current 2020 goal, the carbon tax is not needed. However, we can examine the potential of a carbon tax for additional mitigation in the following way. We next fit a smooth curve through the points of options with unit mitigation cost higher than zero (see the smooth curve in Figure 2). Based on the curve, Table 11 presents the total reduction potentials of the non-C&T sectors with assumed carbon tax levels at \$1 to \$7. Approximately, for every \$1 increase in the carbon tax, an additional 100 thousand tons of CO₂ will be abated in the non-C&T sectors.

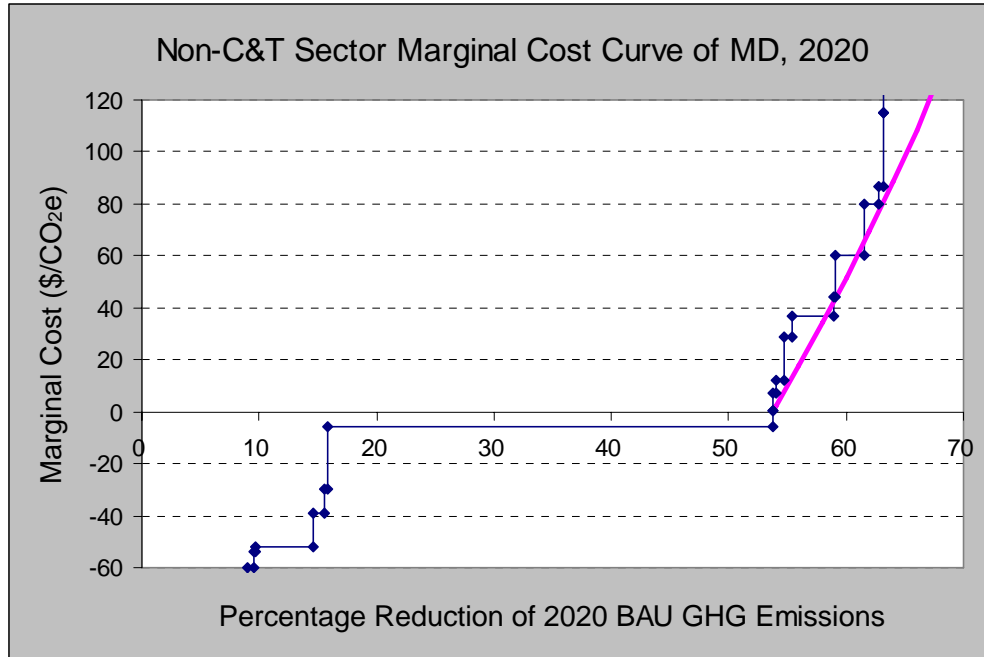


Figure 2. Marginal Cost Curve of Non-C&T Sectors in Maryland

Note: The step curve is developed based on the options data in Table 10. The horizontal axis represents the percentage of GHG emissions reduction, and the vertical axis represents the marginal cost or savings of mitigation. In the figure, each horizontal segment represents an individual mitigation option. The width of the segment indicates the GHG emission reduction potential of the option in percentage terms. The height of the segment relative to the x-axis shows the average cost (saving) of reducing one ton of GHG with the application of the option. The smooth curve is fitted through the points of options with unit mitigation cost higher than zero.

Table 11. Carbon Tax Level and Corresponding Total Reduction Potential in Non-C&T Sectors

| Carbon Tax (\$/tCO ₂) | Total Reduction Potential | | Incremental Reduction per Dollar Increase in the Carbon Tax (thousand tCO ₂) |
|--------------------------------------|---------------------------|-----------------------|--|
| | % 2020 BAU level | in MMtCO ₂ | |
| 0 | 53.71% | 41.31 | |
| 1 | 53.84% | 41.41 | 101.07 |
| 2 | 53.97% | 41.51 | 100.79 |
| 3 | 54.10% | 41.62 | 100.50 |
| 4 | 54.23% | 41.72 | 100.21 |
| 5 | 54.36% | 41.82 | 99.93 |
| 6 | 54.49% | 41.92 | 99.65 |
| 7 | 54.62% | 42.01 | 99.36 |