The Beacon Hill Institute

*TheTransportation Climate Initiative: Its Economic Impacts on Massachusetts**

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Executive Summary

The Transportation and Climate Initiative of the Northeast and Mid-Atlantic States (TCI) describes itself as "a regional collaboration of 12 Northeast and Mid-Atlantic states and the District of Columbia that seeks to improve transportation, develop the clean energy economy and reduce carbon emissions from the transportation sector." Massachusetts is a participating state.[1]

The founding document for the TCI is a "Declaration of Intent," issued in 2010 and signed by transportation and environmental officials in 11 states. The declaration states that the purpose of the TCI is "to reduce greenhouse gas emissions, minimize our transportation system's reliance on high-carbon fuels, promote sustainable growth, address the challenges of vehicle-miles traveled and help build the green energy economy."[1] The Initiative is "facilitated" by the Georgetown Climate Center, which worked closely with the Obama administration in its efforts to design and implement climate change policies.[2]

The Initiative would employ a method called "cap and invest" to achieve its goals. Under the "cap and invest" method, a "program administrator" in a TCI jurisdiction would set a cap on the amount of emissions that fuel distributors may produce. The initial cap would equal current baseline emissions, but the administrator would then, over time, reduce the cap as desired in order to reduce the total emissions being produced.

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[1] Transportation Climate Initiative, (February 3, 2020) https://www.transportationandclimate.org/content/about-us

[2] Transportation Climate Initiative Declaration, (February 3, 2020) https://www.transportationandclimate.org/sites/default/files/TCI-declaration.pdf

[3] Georgetown Climate Center, (February 3, 2020) https://www.georgetownclimate.org/.

The fuel distributor would have to obtain an "allowance" for every ton of emissions produced from the fuel it distributes. Allowances would be put up for auction and provided to the highest bidder.

The reduction in GHG emissions under the various emissions cap scenarios proposed under the TCI would confer economic benefits by abating the adverse effects of climate change. The logic follows that the more stringent the emissions cap imposed, the greater the environmental and economic benefits from mitigating GHG emissions. Potential benefits from such mitigation include avoiding crop and livestock losses, stopping property damages from climate-change-induced flooding, and other impacts caused by climate change.[4]

The Beacon Hill Institute estimated the costs and benefits to Massachusetts of participating in the Transportation Climate Initiative. We report our results for three emissions cap scenarios from 2022 through 2026 to capture the short-term economic impacts on the Massachusetts economy. The scenarios are caps set at 20, 22, and 25 percent of baseline emissions. Table 1 displays the results of a cap set at 22 percent.

If Massachusetts were to set a 22 percent emissions cap on finished gasoline and on-road diesel, emissions would be reduced by .371 million metric tons of carbon dioxide or equivalent (MMTCO2E) by 2022 and .347 MMT of CO2E by 2026. The DICE model projects the social cost of CO2E at $39.95 per metric ton in 2022, increasing to $45.52 by 2026. Using the social costs of CO2E from 2022 through 2026, we project total social benefits of $15 million in 2022 and increasing to $16 million by 2026 in the 22 percent scenario.

[4] U.S. Environmental Protection Agency, Environmental Economics, Economics of Climate Change, https://www.epa.gov/environmental-economics/economics-climate-change.

We use an estimate of revenue resulting from auction allowance proceeds of $450 million annually under a 22 percent emissions cap scenario. Under that scenario, the adverse economic effects of the emissions cap would reduce other tax revenues, resulting in a net increase of $431 million in state tax revenues in 2022 and a net increase of $432 million by 2026.

The price of finished gasoline would increase by 21 cents per gallon and the price of on-road diesel would increase by 42 cents per gallon as a result of the 22 percent emissions cap. In 2022, the first year of implementation, business investment would fall by $229 million, disposable income by $1,524 million, and private employment by 7,629 jobs. The cost per average Massachusetts household would be $585.

By 2026, the cap would reduce business investment by $243 million, disposable income by $1,643 million, and private employment by 6,900 jobs. The cost per average Massachusetts household would increase to $631.

Table 1: The Costs and Benefits of a 22% Cap on Gasoline and Diesel Emissions

Variable	2022	2023	2024	2025	2026
Total dynamic revenue change ($, mil.)	431	431	432	432	432
Private employment (jobs)	-7,629	-7,478	-7,333	-7,193	-6,900
Investment ($, mil.)	-229	-233	-237	-239	-243
Disposable income, real ($, mil.)	-1,524	-1,548	-1,582	-1,607	-1,643
Cost per household ($)	585	595	608	618	631
Total social cost of TCI ($, mil.)	788	775	738	704	671
Total social benefits of TCI ($, mil.)	15	15	15	16	16
Net benefits (-cost) of TCI ($, mil.)	-773	-760	-723	-688	-655

The total loss of output (measured in real GDP) due to the emissions cap would be $788 million in 2022 and $671 million in 2026. This loss represents the total social cost of the emissions cap imposed on Massachusetts. When adding the benefits from the benefits of GHG reduction, the net cost of the emissions cap would be $773 million in 2022 and fall to $655 million by 2026.

The costs of Massachusetts participating in TCI largely outweigh the benefits from the abatement of emissions. While benefits from the reduction of GHG would materialize under an emissions cap, Massachusetts and other cooperating jurisdictions would bear the costs, while all global citizens reap the benefits. Massachusetts lawmakers should keep this in mind when considering the state's participation in TCI.

Introduction

The Transportation and Climate Initiative of the Northeast and Mid-Atlantic States (TCI) Framework for a Draft Regional Policy Proposal, released October 1, 2019, proposes a "Cap and Invest" system in which fuel suppliers would be required to purchase carbon allowances through an auction-based system.[5] The "cap" or limit for carbon emissions is determined through the use of a "combination of baseline emissions for three recent years, and projected emissions estimated through modeling." The cap would be set at a level that then declines every year at a rate chosen by TCI jurisdictions to support their emissions reduction goals. Analysis of the program's impact would also inform the cap level.

After determining the cap, carbon allowances (designated allowances of carbon emissions from the combustion of the fossil fuel component of finished motor gasoline and on-road diesel fuel in the region) would be auctioned off to the highest bidder.

[5] Transportation Climate Initiative, Framework for a Draft Regional Policy Proposal (February 3, 2020) https://www.transportationandclimate.org/sites/default/files/TCI-Framework_10-01-2019.pdf

Accompanying the auction process and new market for carbon allowances, a "regional organization would be used to conduct carbon market monitoring, auction administration and allowance tracking. This would include the establishment and maintenance of a system to collect and manage reported emissions-related data from regulated entities and track allowance accounts." TCI will also monitor emission allowances and transportation fuel markets.

According to the TCI Framework for a Draft Regional Policy Proposal, "Fuel suppliers would be required to report emissions to TCI jurisdictions, plus supporting information. Compliance obligations would be calculated based on the emissions that occur when the affected fuel is combusted, using standard emission factors developed by the United States Environmental Protection Agency (US EPA), California, or other similar sources." In order to monitor emissions, "TCI Jurisdictions", most likely individual states or regional enforcement bodies, would have to create an electronic monitoring system. Reports would be required monthly or quarterly, and would either be verified by a third-party, a government agency, or self-verified.

As the debate over policy responses to climate change intensifies, economists have generally advocated carbon taxes or suggested cap-and-trade laws as possible solutions.[6] Economists view greenhouse gas emissions (GHG) as a negative externality. GHG can be viewed as a negative externality when one considers the effects of the greenhouse gases on crop yields, ocean levels, ocean acidification levels, and a plethora of other areas directly affected by a rise in temperature caused by the greenhouse effect.

[6] National Bureau of Economic Research, Carbon Taxes vs. Cap and Trade: A Critical Review, (August 1, 2013) https://www.nber.org/papers/w19338.pdf

One way to curb an externality (GHG emissions) is to put a price on the harm it causes (shoreline destruction, decreased fishing, etc.). The most common instrument is a tax, which is intended to create a true market price for the externality (in this case, GHG emissions). As with all taxes, the increase in price resulting from a tax is supposed to decrease consumption of the good being taxed. An example of taxes with similar goals are those levied on cigarettes and other so-called "sin taxes." Proponents claim that a carbon tax would give consumers an incentive to decrease their consumption of fossil fuels, which contribute to GHG emissions.

Cap-and-trade systems also impose an additional cost on carbon emissions, albeit in a very different way. The "cap" part of a cap-and-trade system entails establishing a cap of allowable emissions for a region, country, state, or locality. The emissions under the cap are partitioned into pre-determined allowances, which are then either allocated by need or auctioned off to the highest bidder. Those firms or individuals in possession of the allowances are free to trade or purchase the allowances from each other, hence the "trade" in cap-and-trade.

Existing Cap-and-Trade Systems

The European Union, the state of California, and China have instituted cap-and-trade systems akin to the TCI.

The European Union

The European Union instituted the world's first major carbon market and cap-and-trade system in 2005, called the EU Emissions Trading System (EU ET**S)**.[7] As of today, 31

[7] The EU Emissions Trading System, (February 3, 2020) https://ec.europa.eu/clima/sites/clima/files/docs/0005/registered/9825553393-31_friends_of_the_earth_europe_en.pdf

countries in the European Economic Area (EEA) are subject to emissions caps, but each country is granted a different quantity of emissions allowances.[8] Under the EU ETS, companies receive or buy emission allowances that they can trade with one another as needed. They can also buy limited amounts of international credits from emission-saving projects around the world. Emission-saving projects include carbon-capture systems and other mechanisms that remove carbon emissions from the atmosphere.

The EU ETS regulates carbon dioxide (CO2) emissions from power and heat generation, energy-intensive industry sectors including oil refineries, steel works and the production of iron, aluminum, metals, cement, lime, glass, ceramics, pulp, paper, cardboard, acids and bulk organic chemicals, commercial aviation, nitrous oxide (N2O) from production of nitric, adipic, and glyoxylic acids, and glyoxal, perfluorocarbons (PFCs) from aluminum production.[9]

The environmental impact from EU ETS has been studied in detail by the EU and outside entities.[10] According to most recent estimates, during the same period the EU ETS has been in place, total carbon emissions increased, not decreased in the countries regulated by the system during the initial years the cap-and-trade system was implemented (2005-2007). The EU was reluctant to stymie economic growth, especially in countries struggling in the aftermath of the 2008 global recession. To assist these countries in their recoveries, the EU increased the quantity of emissions allotments permitted under the cap to keep the price of carbon-producing products low. The market

[8] Imperial College, "Evaluating the EU Emissions Trading System: Take it or leave it? An assessment of the data after ten years" (October 1, 2016) https://www.imperial.ac.uk/media/imperial-college/grantham-institute/public/publications/briefing-papers/Evaluating-the-EU-emissions-trading-system_Grantham-BP-21_web.pdf
[9] Ibid, 8.
[10] Ibid, 8.

price of carbon under EU ETS reached a record-low of €0.03 in 2007 and did not begin to rise until the EU transitioned ETS from its "Pilot Phase" to "Phase I" in 2008.[11]

Phase I resolved the issues with reducing emissions from the Pilot Phase. Researchers at Imperial College in London, UK concluded that EU ETS led to an estimated 100-200-million-ton reduction (2.4-4.7% reduction) in CO2 emissions during the first two years of Phase I alone.[12] From the beginning of the EU ETS to 2015, revenue collected from the auctioning of allowances totaled €4.9 billion.

California

California launched its cap-and-trade system in 2013.[13] According to the Center for Climate and Energy Solutions, "The cap-and-trade rule applies to large electric power plants, large industrial plants, and fuel distributors (e.g., natural gas and petroleum). Around 450 businesses responsible for about 85 percent of California's total greenhouse gas emissions must comply." The California Air Resources Board (CARB) is the entity responsible for enforcing the cap. The cap-and-trade rules first applied to electric power plants and industrial plants that emitted 25,000 tons of carbon dioxide or equivalent per year or more. In 2015, the program was extended to fuel distributors meeting the 25,000-metric ton threshold. In addition to the freely allocated emissions allowances from the state government, allowances are also sold to the highest bidder via auction. Between 2013 and 2018, California's cap-and-trade auction system generated $9.3 billion in revenue.[14]

[11] Ibid, 8.
[12] Ibid, 8.
[13] Article 5, California Cap on Greenhouse Gas Emissions, (April 1, 2019) https://ww3.arb.ca.gov/cc/capandtrade/capandtrade/ct_reg_unofficial.pdf
[14] California Air Resources Board, (March 19, 2019) https://ww2.arb.ca.gov/news/report-cap-and-trade-spending-doubles-14-billion-2018

Through 2016, the price of gasoline per gallon in California is estimated to have risen by 11 cents and the price of diesel fuel per gallon by 13 cents as a result of California's cap-and-trade system.[15] It is also estimated that since the implementation of a cap-and-trade, motorists spend about $2 billion more annually for transportation fuel.[16]

China

In December of 2017, China formally launched its nationwide emission trading system (ETS).[17] China set the initial price of carbon at $10 per ton, with the cap regulating 1,700 carbon-intensive sectors including energy production. China instituted its cap-and-trade system with goal of decreasing carbon emissions by a quarter or more by 2030.[18] According to Reuters, the nationwide ETS aims to cover 8 billion tons of carbon dioxide emissions per annum from around 100,000 industrial plants when the trading scheme is fully launched.

Trading of carbon on the Chinese ETS market has yet to commence, as China has been developing the necessary regulations and technical infrastructure for the market since 2017. The Chinese expect the first trades in ETS to take place sometime in 2020.[19]

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[15] Legislative Analyst's Office, (March 4, 2016) https://lao.ca.gov/reports/2016/3438/LAO-letter-Tom-Lackey-040716.pdf
[16] Ibid, 15.
[17] "The China Carbon Market Just Launched, And It's the World's Largest. Here's How It Can Succeed" (December 19, 2017) https://www.forbes.com/sites/energyinnovation/2017/12/19/the-china-carbon-market-just-launched-and-its-the-worlds-largest-heres-how-it-can-succeed/#2671f2a37ce6
[18] China Energy Policy Solutions, (July 1, 2017) https://china.energypolicy.solutions/docs/20160704_ExecutiveSummary_EN--FINAL.pdf
[19] Ibid, 18.

Massachusetts Climate Policy

Since 2007, Massachusetts has been a member of the Regional Greenhouse Gas Initiative (RGGI).[20] RGGI is a carbon dioxide cap-and-trade agreement between nine Northeastern states.[21] RGGI imposes a limit on the amount of carbon dioxide (CO2) emitted by all the regulated electric power plants in the region. Each state agrees to issue a fixed amount of allowances corresponding to this limit, proportional to the number of power plants in the state. The participating states agreed to eliminate 10 percent of power sector GHG emissions by 2018.

In August 2008, Massachusetts passed the Global Warming Solutions Act (GWSA).[22] With the law's passage, Massachusetts became one of the first states to enact legislation to combat climate change. The GWSA created a framework for reducing GHG emissions, requiring a 10-25 percent reduction in GHG emissions by 2020 (from the 1990 baseline year), and an 80 percent reduction by 2050. As of 2009, the GWSA stipulates that the Commonwealth's largest emission sources are required to report and provide data on their GHG emissions. In 2016, Massachusetts Governor Charlie Baker signed Executive Order 569, requiring the Executive Office of Energy and Environmental Affairs to create new solutions aimed at mitigating GHG emissions.[23] Under the Order, the state imposes limitations on GHG emissions from Massachusetts state fleet vehicles, on GHG emissions from transportation, on methane emissions from natural gas pipelines, on carbon dioxide emissions from power plants, and on sulfur hexafluoride emissions from

[20] Regional Greenhouse Gas Initiative, https://www.mass.gov/regional-greenhouse-gas-initiative-rggi
[21] See RGGI Inc., https://www.rggi.org/https://malegislature.gov/Bills/191/HD2370.
[22] See https://malegislature.gov/Laws/SessionLaws/Acts/2008/Chapter298.
[23] See https://www.mass.gov/executive-orders/no-569-establishing-an-integrated-climate-change-strategy-for-the-commonwealth.

gas-insulated switchgear. The Order provides no specific policy to achieve said GHG emission targets.

In his 2020 State of the Commonwealth Address, Governor Charlie Baker laid out his self-described "ambitious" plans to transform climate policy in Massachusetts. Baker told legislators, "I'm committing the commonwealth to achieving an ambitious climate goal: net-zero greenhouse gas emissions by 2050." The Governor also reiterated his support for TCI and called for an additional $135 million in operating funds for the MBTA. Both policies aim to cut on carbon emissions from the transportation sector in Massachusetts (which accounts for roughly 40% of Massachusetts' carbon emissions).[24]

It is unclear now if the Massachusetts House of Representatives or State Senate will support TCI, the Governors net-zero greenhouse gas emissions goal or the additional funding for the MBTA.

Massachusetts Carbon Emissions History

If Massachusetts were to participate in the region-wide Transportation Climate Initiative, GHG emissions from the combustion of finished gasoline and on-road diesel destined for final consumption would be capped between 20-25 percent. The Massachusetts economy produces GHG emissions when fossil fuels are burned in the production process. As a result, the transportation, electricity generation, residential, commercial heating, and industrial sectors produce the vast majority of the GHG emissions in Massachusetts. Table 2 displays Massachusetts GHG emissions by sector for

[24] "Baker Homes In On Climate Change, Transportation, Housing In Annual Address" https://www.wbur.org/news/2020/01/22/governor-charlie-baker-zero-net-emissions-mbta-budget-affordable-housing

selected years from 1990.[25] In Table 2, we calculate gross emissions by adding the total energy emissions (CO2E emissions by major sector and natural gas systems emissions), industrial processes emissions, agriculture and land use emissions, and waste emissions.

Table 2: Massachusetts GHG Emissions for Selected Years by Sector (MMTCO2E26)

Emissions	1990	2000	2010	2015	2016	2017
CO2E by Major Sector	88.2	88.8	77.6	70.3	68.5	66.7
Residential	15.3	15.8	13.7	13.7	11.5	12.3
Commercial	8.4	6.8	6.7	7.6	7.0	7.4
Industrial	5.8	5.9	3.9	3.7	3.5	3.2
Electricity	28.2	26.7	22.9	15.6	14.7	13.2
Transportation	30.5	33.6	30.3	29.7	31.7	30.6
Natural Gas Systems	2.4	1.7	1.0	0.8	0.8	0.8
Total Energy Emissions	90.6	90.5	78.7	71.1	69.3	67.5
Industrial Processes	0.7	2.5	3.5	3.9	3.9	4.2
Agriculture & Land Use	0.3	0.3	0.3	0.3	0.2	.2
Waste	2.7	1.1	0.9	0.8	0.8	.8
Gross Emissions	**94.5**	**94.4**	**83.3**	**76.1**	**74.2**	**72.7**
Percentage Change from 1990	0.0	-0.1	-11.8	-19.4	-21.4	-23.0

The data in Table 2 show a few trends. First, energy consumption produces between 93 percent and 96 percent of total Massachusetts GHG emissions and trends downward over the period. Second, although emissions fluctuate with the business cycle, Massachusetts emissions have decreased 23.0 percent from 1990 levels by 2017, the latest year the data is available. As of 2017, the reduction in GHG emissions is only 2.0 percentage points short of the state's 2020 target of a 25 percent reduction from 1990 levels.

Massachusetts GHG emissions from the transportation sector comprise 43 percent of gross GHG emissions. The electricity sector produced the most significant drop in

[25] Massachusetts Department of Environmental Protection, MassDEP Emissions Inventory, Greenhouse Gas Baseline, Inventory & Projection, Appendix C: Massachusetts Annual Greenhouse Gas Emissions Inventory: 1990-2016, with Partial 2017 Data, (accessed March 2019), https://www.mass.gov/lists/massdep-emissions-inventories#2.

[26] Million Metric Tons of CO2 Equivalent.

GHG emissions over the period as the state joined the rest of New England in eliminating coal-fired power plants.[27] The *Massachusetts Global Warming Solutions Act* and the *Regional Greenhouse Gas Initiative* have largely contributed to the decline in Massachusetts GHG emissions over the period.

Table 3: Massachusetts Gasoline and Diesel Fuel GHG Emissions for selected years (MMTCO2E)

Emissions	2012	2013	2014	2015	2016	2017
CO2E by Fuel						
Finished Motor Gasoline	15.2	15.3	15.6	16.1	17.4	17.2
On-Road Diesel	6.7	6.9	7.0	7.1	6.7	6.6
Total Emissions	21.9	22.2	22.6	23.2	24.1	23.8

Finished gasoline and on-road diesel emissions are 23.8 MMTCO2E out of the total emissions from the transportation sector. The total emissions from finished gasoline and on-road diesel in Table 3 establishes the baseline GHG emissions that would be affected by the cap outlined in TCI.

The Costs and Benefits of Massachusetts Participating in TCI

Each participating jurisdiction, in this case Massachusetts, would set a cap on emissions from finished motor gasoline and on-road diesel. We assume that Massachusetts, if they were to participate, would set emissions caps of between 20-25 percent. In our analysis we consider the period 2022 to 2026, to the allow for the implementation of the program.

Emissions subject to the cap would be 23.8 MMTCO2E in 2017, the latest data available. We project Massachusetts emissions from finished gasoline and on-road diesel

[27] Craig Layout, "Last Coal Power Plant in Massachusetts Shuts Down," WGBH, (June 1, 2017), https://www.wgbh.org/news/2017/06/01/news/last-coal-power-plant-massachusetts-shuts-down.

through 2026 using the compound annual growth rate (CAGR) from 2007 to 2017. Table 3 contains the results.

Table 4: Massachusetts Baseline Gasoline and Diesel GHG Emissions Projections

Emissions	2022	2023	2024	2025	2026
CO2E from Fossil Fuel Combustion (Baseline)					
Finished Gasoline	16.5	16.4	16.2	16.1	15.9
On-Road Diesel	6.3	6.3	6.2	6.2	6.1
Total Emissions	**22.8**	**22.7**	**22.4**	**22.3**	**22.0**
CO2E from Fossil Fuel Combustion (20%)					
Finished Gasoline	16.3	16.1	15.8	15.6	15.4
On-Road Diesel	6.2	6.2	6.1	6.0	5.9
Total Emissions	**22.5**	**22.3**	**21.9**	**21.6**	**21.3**
CO2E from Fossil Fuel Combustion (22%)					
Finished Gasoline	16.2	16.0	15.7	15.5	15.2
On-Road Diesel	6.2	6.1	6.0	5.9	5.8
Total Emissions	**22.4**	**22.1**	**21.7**	**21.4**	**21.0**
CO2E from Fossil Fuel Combustion (25%)					
Finished Gasoline	16.2	15.9	15.5	15.2	14.9
On-Road Diesel	6.2	6.1	6.0	5.8	5.7
Total Emissions	**22.4**	**22.0**	**21.5**	**21.0**	**20.6**

We project that baseline emissions subjected under TCI will fall to 22.8 MMTCO2E by 2022 and fall to 22.0 MMTCO2E by 2026. Under a 20 percent cap scenario, we project that emissions will fall to 22.5 MMTCO2E in 2022 and fall to 21.3 MMTCO2E by 2026. In a scenario whereby a 22 percent emissions cap is imposed, we project emissions to fall to 22.4 MMTCO2E in 2022 and decrease to 21.0 MMTCO2E by 2026. And in the scenario where a 25 percent emissions cap is set, we project emissions in 2022 would to be 22.4 MMTCO2E and decrease to 20.6 MMTCO2E by 2026.

The law of demand states that if the quantity demanded (or consumed) goes down, which occurs under an emissions cap, then the price will be driven up. Therefore, as a cap on emissions from the combustion of finished gasoline and on-road diesel is enforced, the prices of each product will increase.

We account for this by calculating the percentage decrease in the quantity of both finished gasoline and on-road diesel, calculating the responsiveness of each product to changes in quantity and applying the resulting change in price of each product to projected prices for 2022. This allows us to calculate the increase in the price of each product due to the various emissions cap scenarios. The Appendix contains the details of these calculations.

The TCI emissions cap would apply only to Massachusetts emissions from the combustion of gasolione and on-road diesel destined for final sale. Both products have very low responses, or elasticities, to changes in quantity. As a result, the proposed emissions cap scenarios would have a significant impact on prices in Massachusetts. In the 20 percent emissions cap scenario, the price of finished gasoline would increase by 18 cents per gallon and the price of on-road diesel by 36 cents per gallon. If a 22 percent emissions cap were imposed, the price of finished gasoline would increase by 21 cents per gallon and the price of on-road diesel by 42 cents per gallon. And in a scenario whereby a 25 percent emissions cap is enforced, the price of finished gasoline would increase by 26 cents per gallon and the price of on-road diesel by 52 cents per gallon.

To analyze the economic and global temperature effects of greenhouse gas (GHG) emission reduction policies, BHI utilized the 2017 Dynamic Integrated model of Climate and the Economy (DICE).[28] As the name of the model indicates, the DICE 2017 model integrates an economic model with a climate model. A thorough description of the DICE 2017 model, as well as results related to different policy guidelines, like the Kyoto

[28] The latest version of the DICE 2017 model is available online at http://nordhaus.econ.yale.edu/DICE2007.htm. We downloaded the model for the runs reported here on April 1, 2019.

Protocol or the Stern Review, is available in Nordhaus (2008).[29] We use the DICE 2017 model to calculate the optimal social cost of CO2E and, in turn, the social benefits of carbon reductions resulting from the various emissions cap scenarios laid out in the TCI modeling.

BHI used the DICE model to calculate the optimal social cost of CO2E for each year of our analysis. We applied the social cost of carbon from the DICE model to our estimate of the reduction in CO2E resulting from the different emissions cap scenarios. Table 5 displays the results.

If Massachusetts participated in TCI, BHI projects emissions would be reduced by .314 MMT of CO2E by 2022 and .297 MMT of CO2E by 2026 in a 20 percent emissions cap scenario. In a 22 percent emssions cap scenario, emissions would fall by .371 MMT of CO2E by 2022 and .347 MMT of CO2E by 2026. And in a 25 emissions cap scenario, emissions would decrease by .459 MMT of CO2E by 2022 and .423 MMT of CO2E by 2026.

The DICE model projects the social cost of CO2E at $39.95 per metric ton of CO2E in 2022, increasing to $45.52 per metric ton of CO2E in 2026. As a result, in a 20 percent emissions cap scenario, the reduction in emissions would provide $12.57 million in social benefits in 2022 and $13.55 million in social benefit in 2026. A 22 percent emissions cap scenario would result in $14.83 million in social benefits in 2022 and increase to $15.82 million in social benefits by 2026. In a 25 percent emissions cap scenario, total social benefits would be $18.32 million in 2022 and rise to $19.25 million by 2026 .

To estimate the economic effects of Massachusetts participating in TCI, BHI has developed a Computable General Equilibrium (CGE) model. The purpose of the BHI model, called MA-STAMP (Massachusetts State Tax Analysis Modeling Program), is to

[29] Nordhaus, William, *A Question of Balance: Weighing the Options on Global Warming Policies*, 1. ed., New Haen, CT: Yale University Press, May 2008.

identify the economic effects of tax changes on a state's economy.[30] Using the STAMP model, we find that the increase in price of finished gasoline and on-road diesel resulting from various emissions caps would generate a less competitive business environment, resulting in slower economic growth, lower employment, disposable income, and investment.

We use estimates of the revenue that would result from auction allowances of finished gasoline and on-road diesel emissions.[31] The resulting revenue would be $300 million annually in a 20 percent emissions cap scenario, $450 million annually in a 22 percent emissions cap scenario, and $600 million in a 25 percent emissions cap scenario.

BHI modified the MA-STAMP model to accommodate the increase in price in both finished gasoline and on-road diesel. First, we introduced the TCI Auction Allowances Fund to the model. We then allocated the Auction Allowances Fund to STAMP's 27 industrial sectors and allocated fund's proceeds (revenues) to industries and government based on employment of each sector relative to the total. The Appendix contains the details of this procedure.

Table 5 shows that a 20 percent emissions cap would reduce investment by $179 million, disposable income by $1,165 million, and private employment by 6,012 jobs in 2022. The cost per average Massachusetts household would be $448 in 2022. The net cost of the emissions cap, that is the total social benefits minus the total social cost (loss of state gross domestic product) would be $655 million. Under a 20 percent emissions cap scenario, the adverse economic effects of the emissions cap would reduce other tax revenues, resulting in a net rise of $287 million in state tax revenues in 2022.

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[30] For a description of the model see www.beaconhill.org.

[31] Climate X-Change "The dollars and cents of carbon pricing in Massachusetts" (May 2, 2019) https://climate-xchange.org/2019/05/02/dollars-cents-carbon-pricing-massachusetts/

As time passes, a 20 percent emissions cap would reduce investment by $191 million, disposable income by $1,281 million, and private employment by 5,560 jobs in 2026. The cost imposed per average Massachusetts household would be $492 in 2026. The net cost of the emissions cap to the economy would be $566 million. Under a 20 percent emissions cap scenario, the adverse economic effects of the emissions cap would reduce other tax revenues, resulting in a net rise of $288 million in state tax revenues in 2026.

Table 5: The Costs and Benefits of a 20% Emissions Cap on Massachusetts

Variable	2022	2023	2024	2025	2026
Dynamic TCI revenue ($, mil.)	300	300	300	300	300
Revenue changes other state taxes ($, mil.)	-13	-13	-12	-12	-12
Total dynamic revenue change ($, mil.)	287	287	288	288	288
Private employment (jobs)	-6,012	-5,904	-5,798	-5,697	-5,560
Investment ($, mil.)	-179	-181	-185	-187	-191
Disposable income, real ($, mil.)	-1,165	-1,201	-1,227	-1,253	-1,281
Cost per household ($)	448	462	471	482	492
Total social cost of TCI ($, mil.)	668	647	623	602	580
Total social benefits of TCI ($, mil.)	13	13	13	13	14
Net benefits (-cost) of TCI ($, mil.)	-655	-634	-610	-589	-566

Table 6 shows that a 22 percent emissions cap would reduce investment by $229 million, disposable income by $1,524 million, and private employment by 7,269 jobs in 2022. On average, Massachusetts households would incur a cost of $585. The net cost of the emissions cap would be $773 million. The adverse economic effects of the emissions cap would reduce other tax revenues, resulting in a net rise of $431 million in state tax revenues.

By 2026, a 22 percent emissions cap would reduce investment by $243 million, disposable income by $1,643 million, and private employment by 6,900. The average Massachussets household would incur a cost of $631. The net cost imposed on the economy from the emissions cap would be $655 million. The adverse economic effects of the emissions cap would reduce other tax revenues, resulting in a net rise of $432 million in state tax revenues.

Table 6: The Costs and Benefits of a 22% Emissions Cap on Massachusetts

Variable	2022	2023	2024	2025	2026
Dynamic TCI revenue ($, mil.)	450	450	450	450	450
Revenue changes other state taxes ($, mil.)	-19	-19	-18	-18	-18
Total dynamic revenue change ($, mil.)	431	431	432	432	432
Private employment (jobs)	-7,629	-7,478	-7,333	-7,193	-6,900
Investment ($, mil.)	-229	-233	-237	-239	-243
Disposable income, real ($, mil.)	-1,524	-1,548	-1,582	-1,607	-1,643
Cost per household ($)	585	595	608	618	631
Total social cost of TCI ($, mil.)	788	775	738	704	671
Total social benefits of TCI ($, mil.)	15	15	15	16	16
Net benefits (-cost) of TCI ($, mil.)	-773	-760	-723	-688	-655

Table 7 shows that a 25 percent emissions cap would reduce investment by $288 million, disposable income by $1,921 million, and private employment by 9,667 jobs in 2022. The cost per average Massachusetts household would be $738. The net cost of the emissions cap would be $923 million. The adverse economic effects of the emissions cap would reduce other tax revenues, resulting in a net increase of $575 million in state tax revenues.

As time passes, a 25 percent emissions cap would reduce investment by $303 million, disposable income by $2,061 million, and private employment by 8,926 jobs in 2026. The total cost per average Massachusetts household would be $792. The net cost imposed on the economy would be $797 million. The adverse economic effects of the emissions cap would reduce other tax revenues, resulting in a net increase of $576 million in state tax revenues.

Table 7: The Costs and Benefits of a 25% Emissions Cap on Massachusetts

Variable	2022	2023	2024	2025	2026
Dynamic TCI revenue ($, mil.)	600	600	600	600	600
Revenue changes other state taxes ($, mil.)	-25	-25	-24	-24	-24
Total dynamic revenue change ($, mil.)	575	575	576	576	576
Private employment (jobs)	-9,667	-9,457	-9,282	-9,100	-8,926
Investment ($, mil.)	-288	-292	-296	-299	-303
Disposable income, real ($, mil.)	-1,921	-1,955	-1,977	-2,025	-2,061
Cost per household ($)	738	751	760	778	792
Total social cost of TCI ($, mil.)	941	936	895	856	816
Total social benefits of TCI ($, mil.)	18	19	19	19	19
Net benefits (-cost) of TCI ($, mil.)	-923	-917	-876	-837	-797

Conclusion

Massachusetts lawmakers have been aggressive in enacting policies to combat climate change. Policymakers passed the *Global Warming Solutions Act* and joined the *Regional Greenhouse Gas Initiative* intending to reduce the state's GHG emissions. Massachusetts is currently more than on track to meet its goal of a 25 percent reduction in GHG from 1990 levels.

Cap and trade schemes are a problematical tool to address climate change, with consequential costs that directly hit household's disposable income.

Massachusetts participating in TCI would confer benefits to the global community from the reduction GHG emissions. However, we suspect that such a large increase in the price of gasoline will force gasoline entering the state to be formulated with a larger amount of ethanol. If this were to happen, whichever state produces the ethanol could create enough emissions to offset the reduction in emissions in Massachusetts or other TCI jurisdictions. Also, while transportation emissions represent a large portion of total emissions in the TCI region, any emissions cap on finished gasoline and on-road diesel in Massachusetts and other TCI jurisdictions would have unnoticeable effects on global emissions. The Massachusetts emissions subject to the propsed emissions caps are but a fraction of global emissions. Global GHG emissions were 50.9 gigatons of CO2E in 2017, compared to Massachusetts emissions subjected to emissions caps under TCI of 23.8 MMTCO2E.[32] Nonetheless, the reduction in Massachusetts GHG emissions and other TCI jursidictions would provide an economic benefit against the baseline case of no emissions reduction.

Massachusetts GHG emissions subject to the proposed carbon taxes are only 0.04 percent of global GHG emissions, which grew at a rate of 1.2 percent between 2016 and 2017. The global GHG emissions growth between 2016 and 2017 is more than twenty-five times greater than the Massachusetts emissions subject to the carbon tax.

The Massachusetts economy would suffer under the proposed emissions cap scenarios. An emissions cap, while providing negligible benefits, would cost thousands of jobs, millions in investment, and millions of dollars in lower incomes and real GDP by 2026.

The costs of Massachusetts partaking in the TCI far outweigh the benefits. Moreover, citizens of Massachusetts along with other TCI jurisdictions would face the burden of the costs, while all citizens of the world share the small benefits.

Appendix

BHI used its multisector STAMP model to estimate the economic cost of a proposed cap and investment of finished gasoline and on-road diesel in Massachusetts. The existing models provide fields in which we can enter changes in the state income,

[32] Netherland Environmental Assessment Agency, "Trends in global CO2 and total greenhouse gas emissions: 2018 report," (May 12, 2018), https://www.pbl.nl/en/publications/trends-in-global-co2-and-total-greenhouse-gas-emissions-2018-report.

corporate, sales, and motor fuels tax. We modified the model (1) adding separate taxes on gasoline and diesel, and (2) adding the Auction Allowances Fund under the TCI, and allocate the resulting revenue to the sectors who will benefit. We assume that 50 percent of the Auction Allowances Fund will be spent towards MBTA spending, and the other 50 percent towards investment in improvements of energy efficiency such as electric car charging stations.[33]

BHI then forecasted the baseline emissions from the combustion of finished gasoline and on-road diesel within the TCI region, using a compound annual grwoth rate (CAGR). BHI estimated that baseline emissions in the region will fall by 8 percent over the period 2022 through 2032. BHI next estimated scenarios whereby CO2E emissions from the consumption of on-road diesel and finished motor gasoline destined for final sale were capped at 20 percent, 22 percent and 25 percent, leading to an increase in the price in subjected motor fuels. We subtracted the annual cap in emissions by the baseline fall in emissions to find our annual price increase for both products in Massachusetts. To accomplish this, BHI (1) estimated the price elasticities of demand for the different fuels specified in the Transportation and Climate Initiative MOU, (2) forecasted the price of fuels for the time period, and (3) estimated the price change for each fuel that would result from the various emissions cap scenarios.

BHI utilized data for on-road diesel and finished motor gasoline and consumption from the U.S. Department of Energy's Energy Information Administration (EIA) for Massachusetts to calculate price elasticities of demand for each product.[34] We calculated

[33] "Transportation and Climate Initiative Agreement to Deliver Northeast At Least $1.4 Billion in Transit System Investment" (December 17, 2019) https://www.mass.gov/news/transportation-and-climate-initiative-agreement-to-deliver-northeast-at-least-14-billion-in

[34] U.S. Department of Energy, Energy Information Administration, Massachusetts State Profile and Energy Estimates, More Data & Analysis in Massachusetts by Source, (accessed March 2019), https://www.eia.gov/state/search/#?1=79&2=200.

price elasticities of demand for the finished gasoline and on-road diesel portion of the transportation sector. We used a log-log model to calculate the elasticities using the following equation:

$$\log(consumption) = \beta + \log(price) + \varepsilon,$$

where β is the intercept, α is the elasticity, and ε is the error term.

Table A1: Elasticities of Demand for Finished Gasoline and On-Road Diesel in Massachusetts

Fuel	Transportation
On-Road Diesel	-0.112
Gasoline	-0.197

The EIA provides historical price data for each motor fuel in the transportation sector. However, we need to estimate the future prices of the motor fuels for our period. The CME Group provides futures prices for gasoline (RB) and fuel oil products (MF). We used the percentage change in the futures prices to project the motor fuel prices for 2022.

The EIA provides carbon dioxide emissions coefficients by fuel per unit of volume and per million BTU. We converted the emissions coefficients into metric tons for motor fuels to match the measure used in the EIA price data.

Using our price elasticity of demand we calculated the price change that would result from the cap in carbon emissions for on-road diesel and gasoline. The EIA provides data on emissions by motor fuel in the transportation sector.

We assume that the emissions reduction under the cap would fall in line with the reduction in the supply of on-road diesel and gasoline. Thus, we divide the percentage decrease in quantity by the elasticity under the carbon emissions cap for on-road diesel and gasoline, and then multiply that result by the forecasted price without the cap to get our estimate of the increase in price. For example, we multiplied the decrease in the quantity of gasline (1.38 percent) by the elasticity for gasoline (-0.197) to calculate the increase in the price in gasoline of 18 cents in 2022. Once again, this process was repeated for on-road diesel fuels.

Next, we insert the increase in the price of on-road diesel and gasoline that would result under the proposed emissions cap into our models. We also use obtained estimates of the resulting revenue figures from the proceeds of auctions allowances as inputs to the STAMP models.

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