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# What Does it Take to Reduce Massachusetts Emissions 50% by 2030? Challenges Meeting Climate Goals Under Current Legislation (S.2500)

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**What Does it Take to Reduce Massachusetts Emissions 50% by 2030?**
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**Executive Summary:** To do its part in the global fight against climate change, Massachusetts must achieve net zero greenhouse gas emissions by mid-century, and aggressive intermediate goals are essential to ensure that the state is on track for net zero. Senate bill 2500, "An Act setting next generation climate policy," stipulates that 2030 emissions must "not be less than 50% below the 1990 emissions level." In 2017, Massachusetts carbon dioxide emissions were 22% below 1990 levels, so the state will need to reduce annual emissions by an additional 28% of 1990 levels by 2030. **If enacted, S.2500 would give the state important new tools that would significantly reduce emissions. However, our analysis suggests that additional policies beyond those in S.2500 will likely be necessary to reliably achieve the 2030 goal of cutting emissions in half from 1990 levels.**

With no new policies enacted (but not accounting for COVID-19), we estimate that 2030 emissions will be roughly 35% below 1990 levels (Figure 1, BAU). We use a range of policy proposals to approximate the key policies in S.2500: the Transportation and Climate Initiative cap and invest program, a net zero stretch building code, and a moderate carbon price ($29/MT rising to $48 in 2030—roughly similar to one in a recent legislative proposal) in the residential, commercial, and industrial sectors. We use published modeling results to approximate these policies and estimate that they would reduce emissions by an additional 6% below 1990 levels (~41%). This leaves an emissions reductions shortfall of ~9% (or 8 million metric tons of $CO_2$, roughly the equivalent of 1.7 million passenger vehicles) in 2030 (see Fig. 1).

To reach a 50% reduction by 2030, Massachusetts could implement a higher carbon price (e.g. $58/MT rising to $95 by 2030), which would be possible under S.2500. Some (but not all) models suggest that a higher carbon price alone would be sufficient to reach 50% of 1990 levels by 2030. Another option (not in S.2500) is to enact an ambitious clean electricity standard to reduce electricity emissions. To ensure we reach the 2030 goal, robust policies will be needed in all major sectors of the state's economy, with electricity sector decarbonization particularly important (Fig. 1, Stringent case).

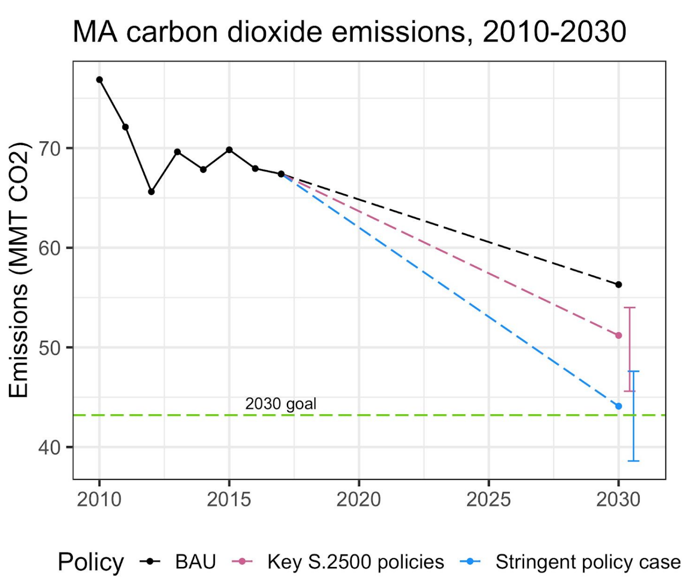


*Figure 1: Projected MA emissions through 2030. The business-as-usual (BAU) case includes existing policy only, key S.2500 policies estimates the effect of policies added under the bill, and the stringent policy case outlines a scenario in which MA could achieve the 2030 goal from S.2500. The vertical bars show the range of carbon price projections from the models in our data set. Although S.2500's targets would cover all greenhouse gases, our analysis includes $CO_2$ only.*

**Background:** Recently, Massachusetts has moved to pursue more aggressive climate goals. In 2008, Massachusetts enacted the Global Warming Solutions Act (GWSA), which set the state's 2050 greenhouse gas emissions limit at 80% of 1990 levels. Based on the Intergovernmental Panel on Climate Change's 2018 report, global emissions must reach net zero (emissions minus sinks like forest regrowth) by mid-century in order to limit warming to 1.5°C above pre-industrial levels and avoid the most catastrophic effects of climate change (IPCC, 2018). The earlier goal of the GWSA is not consistent with such rapid decarbonization, especially given that wealthier and more technologically advanced regions like Massaachusetts will need to reach net zero sooner than mid-century for the global goal to be feasible. In April, Governor Baker officially tightened the state's target to net zero by 2050.

S.2500, "An Act setting next generation climate policy," builds a framework to reach this ambitious goal of net zero emissions by 2050, with intermediate goals every five years beginning in 2020—including a target of 50% below 1990 levels by 2030.

To achieve these reduction goals, bill S.2500, among other measures:

- Establishes market-based compliance mechanisms—such as carbon taxes or cap and trade systems—in the transportation, commercial, industrial, and residential sectors
- Mandates the creation of a net zero stretch energy code
- Institutes a Climate Policy Commission to monitor emissions progress
- Requires the Department of Public Utilities to consider greenhouse gas emissions in its decision-making

S.2500 is part of a three-bill climate package that also includes S.2498, "An Act to accelerate the transition of cars, trucks and buses to carbon-free power," and S.2499, "An Act relative to energy savings efficiency." Of the three bills, S.2500 would have by far the largest impact on statewide emissions.[1] The Senate passed S.2500 in January 2020, and it was subsequently referred to the House Ways and Means Committee (Bill S.2500, 2020). The COVID-19 pandemic absorbed much of legislators' attention in the following months, but S.2500 was amended as H.4912 and passed by the House on July 31st. The two bills will now go into conference. H.4912, "An Act creating a 2050 roadmap to a clean and thriving commonwealth," would also establish a 2050 deadline for net zero emissions, with an interim 2030 limit that "shall be at least 50 percent below the 1990 level." However, H.4912 leaves most specific policies to be defined in the future (Bill H.4912, 2020).

A key question is whether the measures that the EEA (Executive Office of Energy and Environmental Affairs) and other parts of the Massachusetts government are likely to undertake as a result of S.2500 will be sufficient to meet the bill's emissions targets, and specifically the 2030 target. Historically, the two Massachusetts sectors with the highest emissions are transportation and electricity generation, but the

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[1] S.2498 would decarbonize the MBTA and conduct a study on the electrification of other state- and municipally-owned vehicles. Importantly, this bill would reduce urban pollution (Cronin, 2020), a key environmental justice concern. However, the MBTA only accounted for 0.25 MMT $CO_2e$ in 2016, less than 1% of total MA transportation emissions (Lasker, 2017). S.2499 would update appliance standards for increased energy and water efficiency (Cronin, 2020). Energy efficiency is central to building decarbonization, but this bill by itself would not have a noticeable impact on statewide emissions.

EEA's freedom under S.2500 to design new emissions-reducing policies in these sectors may be limited. In the transportation sector, there is the general expectation that reductions would be met through participation in the multi-state Transportation and Climate Initiative. In the electricity sector, S.2500 relies on existing policies to reduce emissions and does not add new carbon pricing authority. While electricity emissions are already covered under a carbon price through the multi-state Regional Greenhouse Gas Initiative and by a Renewable Portfolio Standard and Clean Energy Standard, those measures are not as aggressive as standards recently adopted in other states.[2]

While this paper focuses on the emissions reductions that are likely to occur as a result of S.2500, it is worth noting that climate legislation is inextricably connected to social justice and equity considerations. For example, carbon prices can be designed to benefit low-income households (Rosenberg, Toder & Lu, 2018). California's carbon pricing policy explicitly invests a significant portion in, or for the benefit of, disadvantaged communities (CalEPA, 2020). In addition, policies targeting carbon pollution also reduce other pollutants, offering significant public health co-benefits (Karlsson, Alfredsson & Westling, 2020). A Harvard study found that between 2017 and 2040, air pollution reductions from a modest carbon price in Massachusetts could save 82–590 lives within the state (63%) and in surrounding areas (Buonocore et al. 2018). S.2500 would therefore offer immediate, tangible benefits to Massachusetts residents in addition to helping avoid the worst longer-term effects of climate change.

**Approach:** Our analysis provides a rough quantitative assessment of whether the provisions in S.2500 are likely to hit the bill's 2030 target. We used publicly available data from prior modeling to estimate Massachusetts emissions in the five major emissions-producing sectors (transportation, residential, commercial, industrial, and electric power) under three cases. The business as usual (BAU) case only includes the effects of existing policy. The S.2500 proxy case models the effects of policies added under the bill, including a moderate carbon tax similar to other recent carbon tax proposals in the state. The stringent policy case outlines a scenario in which MA could reliably achieve the 2030 goal from S.2500 through implementation of a more aggressive carbon price and an updated clean electricity standard. An important caveat is that S.2500 covers all types of greenhouse gas emissions, including methane, but we only consider carbon dioxide in our analysis, as it is the largest and most easily regulated source of emissions.

To establish the BAU case, we used emissions data from the 2020 Annual Energy Outlook prepared by the Energy Information Administration. For the transportation sector, we used Transportation and Climate Initiative (TCI) modeling to determine BAU emissions (TCI, 2019b). We note that these projections (which show a reduction to 35% below 1990 levels by 2030 across all sectors) pre-date the COVID-19 pandemic, which has significantly depressed emissions in the short term and may reduce them as far out as 2030 (Larsen et al. 2020).[3] Rather than run new models to project the impacts of S.2500, we used data

[2] Maine's RPS reaches 80% in 2030, New York 70% in 2030 (100% by 2040), and Vermont 75% in 2032 (NCSL, 2020). In contrast, the Massachusetts RPS is only 35% in 2030, and the CES (which expands upon the RPS) is 40% (MassDEP, 2020).

[3] Recent work by the Rhodium group suggests *national* emissions in 2030 may be as much as 12% lower depending upon the pace of the recovery from COVID-19. However, we expect the emissions benefit in New England to be much smaller. The significant reductions in Rhodium occur in electricity and transportation. Because coal

from Stanford Energy Modeling Forum (EMF) Model Intercomparison Project 32 (2018) to examine the effects of a carbon tax in the residential, commercial, and industrial sectors (using national-level and regional-level responses to approximate emissions reductions). To estimate the effects of carbon pricing in the transportation sector, we again used projections from TCI. We also added a crude estimate of potential savings from the net zero building stretch code.

**S.2500 would significantly reduce emissions, but modeling suggests it would fall short of the 2030 target:** In addition to previously existing measures, the S.2500 proxy case includes estimates of a modest carbon price in the commercial, industrial, residential, and transportation sectors and a net zero building stretch code. S.2500 does not include a new carbon price for the electric power sector, presumably because it is already part of a regional cap and trade program (RGGI, the Regional Greenhouse Gas Initiative).

The most likely way that Massachusetts would implement a carbon price in the transportation sector as part of S.2500 is through the Transportation and Climate Initiative (TCI), a collaboration of twelve Northeast and Mid-Atlantic states (plus DC) that aims to reduce greenhouse gas emissions. In 2019, TCI released a draft proposal for a cap and invest plan which would set a cap for all on-road gasoline and diesel emissions (TCI, 2019a). The cap would be reduced by 20–25% from 2022 to 2032, and proceeds from allowance sales would be invested in green infrastructure projects. In the TCI reference case, emissions in the Northeast are projected to decrease by 19% from 2022 to 2032, although they will remain at a higher level if federal standards are relaxed. The cap and invest program would reduce emissions an additional 1.5–5% below the reference case[4] (Appendix C). Lower-post COVID-19 travel could reduce the revenues from TCI and therefore the impact of these investments; at the same time, it is possible that MA could reduce emissions more than the collaborative as a whole with strong state policies.

In the commercial, industrial, and residential sectors, it is less certain what type of carbon price the EEA would choose to implement. For our analysis, we assumed that the EEA would adopt carbon prices similar to those in H.2810, a recent carbon tax bill with an explicit price trajectory.[5] We represented the carbon price in these sectors with a moderate tax that begins at $29 per metric ton (MT) $CO_2$ (2019 dollars) and rises at 5% a year, reaching $48 per MT $CO_2$ in 2030. Under S.2500, the carbon price in the commercial and industrial sectors could be implemented as late as 2025, and in the residential sector as late as 2030. To obtain an optimistic estimate of the bill's effects, we assumed that both prices would begin early in this decade (or, more precisely, that the impact in 2030 is the same as EMF modeling, which assumed a start in 2020). The median reduction from this tax trajectory is 3.3 million metric tons (MMT) CO2, but model estimates range from 0.5 to 8.9 MMT. (See Appendix B for more information.)

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retirements have already largely occurred in New England, the bulk of the additional reductions in electricity will occur in other parts of the US. Similarly, we assume that transportation emissions will be covered by a cap-and-trade system under S.2500, which will have the same cap (with a lower allowance price) if BAU emissions turn out to be lower post-COVID-19.

[4] This estimate includes the effects of both the cap reduction and green investments (TCI, 2019b).

[5] H.2810, filed in 2019, was a popular bill with 107 cosponsors in the Massachusetts House.

S.2500 also mandates the development of a net zero stretch code. Massachusetts first implemented a stretch code as part of the Green Communities Act in 2008. Towns elect to replace their base building code with the more energy efficient stretch code in exchange for grant eligibility (GCD, 2019). Currently, more than 80% of MA residents live in communities with the stretch code in place (DOER, 2019). A net zero stretch code would require newly constructed buildings to be highly efficient, usually entailing electrification, and to produce or purchase renewable energy to meet their remaining energy demand (USGBC, 2019). By 2030, we very roughly estimate that the net zero code would reduce emissions on the order of 0.5 MMT $CO_2$ (Appendix D). Because of the slow turnover of building stock, much of the net zero code's effects would take place after 2030.

As shown in Figure 2, the policies in the S.2500 proxy case (with a moderate carbon price) would reduce emissions by 41% of 1990 levels, well short of the 50% goal. Despite variation in the projected effect of the carbon price, even the most optimistic estimate from the modeling data falls short of the 2030 goal (full range 38–47% reduction, Figure 1). Accounting for COVID-19 might close the gap for the most optimistic carbon price cases, but not reliably.

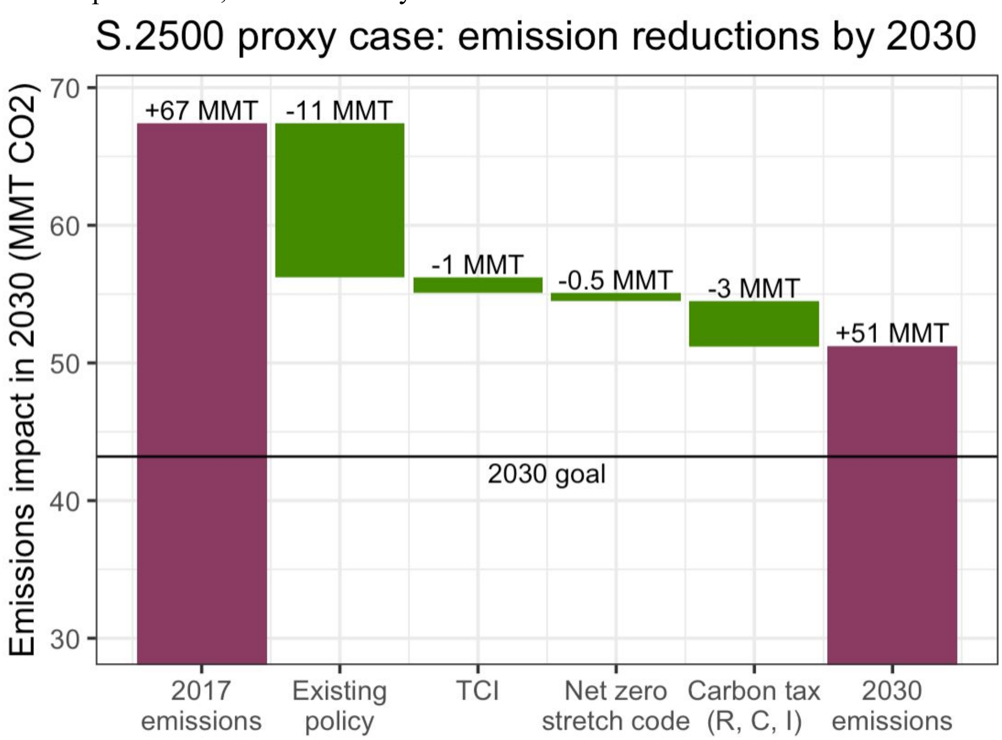


*Figure 2: Reductions by policy in the S.2500 proxy case in 2030. Red bars show emissions in a given year, and green bars show reductions by policy in 2030 from 2017 levels. The value of carbon tax reductions is the median from the EMF models. The TCI reduction assumes that MA enacts a 25% cap reduction 2022–2032, which is the most ambitious option in TCI's current cap and invest proposal. Net zero stretch code estimate is only approximate.*

**An aggressive carbon price can reach the 2030 goal but not in most projections:** Because S.2500 does not specify a price trajectory, the EEA could choose to institute a higher carbon price. We modeled this possibility with an EMF tax trajectory that begins at \$58/MT in 2020 and increases at 5% a year, reaching \$95 in 2030 (\$2019). The median reduction from this policy is 5.2 MMT $CO_2$ by 2030, but values range from 1.8 MMT to 10.7 MMT.[6] Combined with existing policy, TCI, and the stretch code, this results in overall reductions of 39–49% below 1990 levels. The stringent carbon tax reduces emissions to within 1% of the goal only if one considers the most optimistic model result for each sector. Under all other model combinations, the reductions still fall short of the goal. There is reason to believe that economic models tend to underestimate the effectiveness of carbon pricing (Barron, 2018), and a post-COVID-19 economy might also keep emissions lower than projections—even to the end of the decade (Larsen et al. 2020). However, using the data currently available, it appears that policies would need to be added to S.2500 or in subsequent legislation to reliably achieve the 2030 goal.

**Hitting the 2030 goal requires further addressing emissions from electricity and/or transport:** Despite the shortfall in the S.2500 proxy case, reaching 50% of 1990 levels by 2030 is economically and technically feasible in Massachusetts. Part of the challenge in the proxy case is that a framework relying on existing policy in the electricity sector misses opportunities in the sector that many analysts agree is easiest to decarbonize (UC Berkeley, 2020). Similarly, while the TCI program will help enable emissions reductions of up to 24% in the transportation sector, this sector produces by far the largest share of $CO_2$ emissions in the Commonwealth (45% in 2017, Appendix A).

One example of how Massachusetts could meet the 2030 goal while maintaining collaborations in regional policy is by combining a stringent carbon price with a strengthened clean energy (i.e. electricity) standard (CES) or renewable portfolio standard (RPS). Together, these policies bring Massachusetts within range of the goal, as shown in Figure 3.[7]

Instituting a stronger CES or RPS would dramatically improve MA's chances of meeting the 2030 emissions goal. Clean energy standards require that electric utilities provide a certain percentage of electricity each year from low-carbon sources, including renewables, nuclear, and hydropower (MassDEP, 2018). The current CES standard, enacted in 2017, expands upon the older RPS (renewable portfolio standard) and reaches 40% by 2030 (MassDEP, 2020). Because municipal light boards and municipal electric departments are exempted from the standard, the effective CES is only about 34% in 2030.[8] Strengthening the CES is not part of S.2500, but language strengthening the RPS was included in H.4912. Joe Biden announced that if he is elected as United States president, his climate plan would include an Energy Efficiency and Clean Electricity Standard that would completely decarbonize the power sector by 2035 (Biden, 2020)—although it would require sufficient votes in the U.S. Congress.

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[6] This is similar in magnitude to the results of the 2014 study performed by Breslow, Hamel, Lucknow, and Nystrom, which is the only report to date that specifically analyzes carbon pricing in MA. Breslow et al. modeled three economy-wide carbon tax trajectories, beginning at \$11/MT $CO_2$ in 2016 and reaching \$43-\$70/MT by 2030 (\$2019). They found that from the 2020s onward, a carbon tax would reduce emissions an additional 5-10% of 2013 levels below the BAU projection. In our analysis of 2030 emissions, TCI and a carbon tax in the commercial, residential and industrial sectors reduce emissions by an additional 3%–17% of 2013 levels beyond the BAU case, depending on the tax stringency and model. The median for the modest tax plus TCI is 6% and for the stringent tax plus TCI is 9%, similar to the percentages in Breslow et al.

[7] A significant reduction in electricity sector emissions could also be accomplished with a robust carbon price on electricity sector emissions within the state and power imports. We have not analyzed that policy here.

[8] In 2018, municipal electricity accounted for 14% of retail sales (EIA, 2019). If that percentage stays relatively constant over the next decade, the CES will only apply to ~86% of electricity sales.

Massachusetts could implement a standard of comparable stringency, following the model of S.1958/H.2836, "An Act transitioning Massachusetts to 100% renewable energy," which would similarly decarbonize the electricity sector, including municipal plants, by 2035 (Bill S.1958, 2019). Other states in the Northeast already have more stringent programs. For example, Maine's RPS reaches 80% in 2030, New York 70% in 2030 (100% in 2040), and Vermont 75% in 2032 (NCSL, 2020). These policies can be combined with other measures like low-income housing efficiency upgrades to help protect vulnerable households from any potential price increases.[9]

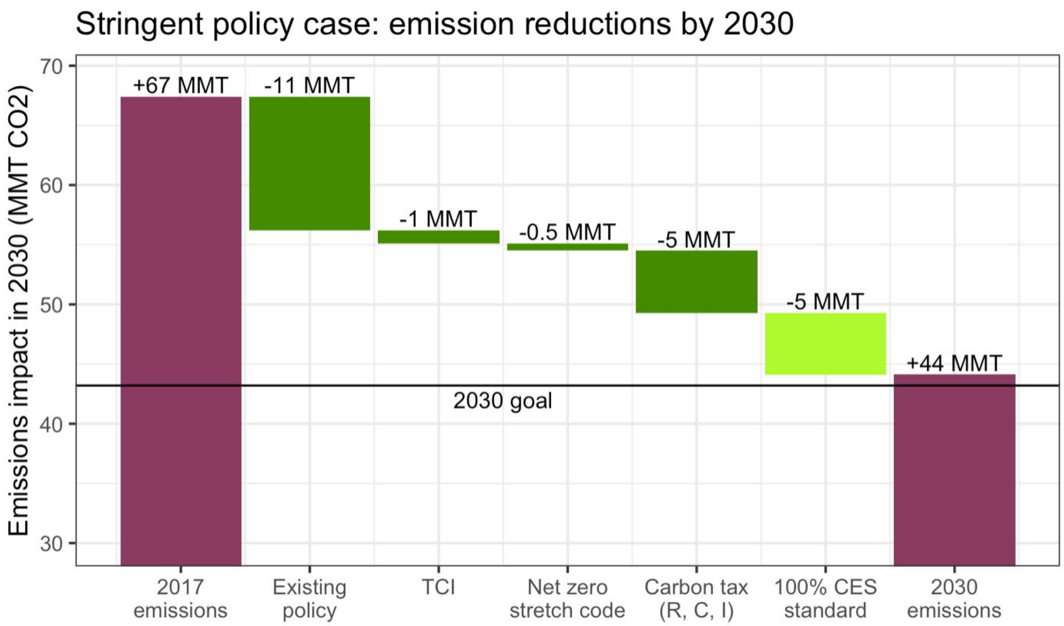


*Figure 3: Emissions reductions by source in the stringent policy case. Red bars are emissions in a given year, and green bars show reductions by policy 2017–2030. The CES is not part of S.2500 and would require additional legislation. For simplicity, we assume that the strengthened CES would reach 100% in 2030. The value of carbon tax reductions is the median from the EMF models; the full range overlaps with the 2030 goal. Net zero stretch code estimate is only approximate.*

Strengthening the CES would also pave the way for future emissions reductions. Decarbonization in the other sectors mainly occurs through electrification, and it is most effective if the grid itself is fully decarbonized. Transitioning space heating to electric heat pumps and replacing fossil-fuel powered vehicles with EVs will increase demand for electricity, and both measures produce the largest air quality and climate benefits with a fully decarbonized grid.

Because Massachusetts electricity emissions are also covered under RGGI, a policy concern could be that a reduction in MA electricity emissions under a tighter CES/RPS would be offset by increases in other

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[9] The New England Clean Energy Connect, scheduled to come online in 2022, would provide Massachusetts with 9.45 TWh of hydropower from Quebec annually (~17% of annual state electricity consumption (EIA, 2019)). If completed successfully, this project would also lower the cost of CES compliance and help prevent electricity price increases (Hoagland and Dobbs, 2018).

states, who could buy the cap and trade allowances Massachusetts would have used (the so-called "waterbed effect") (Burtraw and Keyes, 2018). However, RGGI allowances have traditionally traded at or near the price floor (CRS, 2019) and the current COVID-19 crisis may create a further surplus. Under these conditions, a tightened CES can be expected to have at least some effect on regional emissions. Regardless, the current RGGI caps do not put the region on a trajectory for rapid decarbonization. An aggressive CES in Massachusetts would come closer to representing the kinds of policies needed across the region and would, on a state-level basis, reduce emissions.

**All sectors need to be addressed to ensure continued reductions in emissions after 2030:** As noted above, the stringent policy case is sufficient to meet the 2030 goal, but even that scenario may leave several areas of emissions under-addressed. Achieving net zero emissions by 2050 will require action in these areas. Most importantly, Massachusetts will need to confront the transportation sector's large share of emissions. Even under the highest TCI cap reduction scenario, emissions in the transportation sector would be about 23 MMT in 2030. To bring these emissions down by 2050, the state will need aggressive policies to increase the prevalence of electric vehicles, improve public transport, and reduce vehicle miles traveled through planning, funding, finance, and other measures. Building codes are also essential to ensure that expensive retrofits are not required post-2030.

In addition, Massachusetts will need to address emissions of greenhouse gases other than carbon dioxide, which we do not analyze here. These gases—which include methane, nitrous oxide, and fluorine gases—accounted for an additional 6 MMT $CO_2e$ in 2017. Challenges reducing these emissions may require even greater $CO_2$ reduction efforts to hit the overall target.

**Conclusions:** This analysis is a rough attempt to understand the potential impact of carbon pricing and other policies under S.2500. Predictions of the reductions in emissions from carbon pricing vary significantly with few state-specific estimates available. As a result, *policymakers and advocates should not place too much weight on any specific numerical results.* However, we can draw a number of provisional conclusions based on our analysis:

- Massachusetts has already made significant headway in reducing carbon pollution, cutting $CO_2$ emissions to 22% below 1990 levels in 2017.
- S.2500 would represent a huge step forward in emissions reductions, instituting a carbon price in the transportation, residential, industrial, and commercial sectors and adopting important building code provisions. This would put Massachusetts well ahead of states that have ambitious climate goals but no significant policies to reach them.
- However, policymakers are likely to be disappointed if they expect to reach the 2030 goal (a 50% reduction) with TCI, existing electricity sector policy, and carbon prices similar to H.2810 in the remaining sectors.
- In particular, further emissions reductions from electricity are possible by 2030. For example, Massachusetts could strengthen its CES or RPS standards.
- A robust carbon price in most sectors, combined with a more ambitious electricity sector policy, would put MA well on track to a 50% reduction in $CO_2$ emissions by 2030.
- Other mixes of policies could also be combined to hit this target and position the state for the deeper reductions needed to hit a longer-term (but rapidly approaching) net zero goal.

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**Author Contributions**
ARB conceived the project, LEM, TWD, and AIB developed the initial analysis of S.2500 pricing provisions for ENV 323 at Smith College, LEM significantly expanded and updated the analysis using EMF data and expanded policies, LEM and ARB drafted the white paper.

## References

Barron, AR. 2018. Time to refine key climate policy models. *Nature Climate Change.* DOI: 10.1038/s41558-018-0132-y

Barron, AR, Fawcett, AA, Hafstead, MAC, McFarland, JR, Morris, AC. 2018. Policy insights from the EMF 32 study on US carbon tax scenarios. *Clim Change Econ,* **9**(1). DOI: 10.1142/S2010007818400031

Breslow, M, Hamel, S, Lucknow, P, and Nystrom, S. 2014. Analysis of a carbon fee or tax as a mechanism to reduce GHG emissions in Massachusetts. Massachusetts Department of Energy Resources. http://climate-xchange.org/wp-content/uploads/2015/05/DOER-CTax-study-Exec-Summ-010715.pdf

Biden campaign. 2020. The Biden plan to build a modern, sustainable infrastructure and an equitable clean energy future. Retrieved July 28, 2020 from https://joebiden.com/clean-energy/

Bill H.2810. 2019. The 191st General Court of the Commonwealth of Massachusetts. Retrieved June 24, 2020, from https://malegislature.gov/Bills/191/h2810

Bill H.4912. 2020. The 191st General Court of the Commonwealth of Massachusetts. Retrieved July 31, 2020, from https://malegislature.gov/Bills/191/H4912

Bill S.1958. 2019. The 191st General Court of the Commonwealth of Massachusetts. Retrieved June 23, 2020, from https://malegislature.gov/Bills/191/S1958

Bill S.2500. 2020. The 191st General Court of the Commonwealth of Massachusetts. Retrieved June 18, 2020, from https://malegislature.gov/Bills/191/S2500

Buonocore, JJ, Levy, JI, Guinto, RR, Bernstein, AS. 2018. Climate, air quality, and health benefits of a carbon fee-and-rebate bill in Massachusetts, USA. *Environ. Rse. Lett.* **13**(11). DOI: 10.1088/1748-9326/aae62c

CalEPA. 2020. California climate investments to benefit disadvantaged communities. California Environmental Protection Agency. Retrieved July 10, 2020 from https://calepa.ca.gov/envjustice/ghginvest/

Cronin, T. 2020. Mass. Senate's climate bills: Overview, summary, and context. Climate XChange. https://climate-xchange.org/2020/01/23/mass-senates-climate-bills-overview-summary-context/

CRS. 2019. The Regional Greenhouse Gas Initiative: Background, impacts, and selected issues. Congressional Research Service. https://crsreports.congress.gov/product/pdf/R/R41836

DOER. 2019. Stretch code adoption by community. Massachusetts Department of Energy Resources. https://www.mass.gov/doc/stretch-code-adoption-by-community-map/download

EEA. 2018. Commonwealth joins regional states to reduce transportation emissions [press release]. Executive Office of Energy and Environmental Affairs. https://www.mass.gov/news/commonwealth-joins-regional-states-to-reduce-transportation-emissions

EIA. 2018. CE2.2 Fuel consumption in the Northeast - totals and averages. Energy Information Administration: 2015 Residential Energy Consumptions Survey. data.https://www.eia.gov/consumption/residential/data/2015/index.php?view=consumption

EIA. 2019. Massachusetts electricity profile 2018. Energy Information Administration. Retrieved June 24, 2020 from https://www.eia.gov/electricity/state/Massachusetts/

GCD. 2017. 2017 stretch energy code. MA Green Communities Division. https://www.mass.gov/files/documents/2017/11/21/stretch-energy-code-overview.pdf

Hoaglund, RH, II, Dobbs, B. 2018. Petitions for Approval of Proposed Long-Term Contracts for Renewable Resources Pursuant to Section 83D of Chapter 188 of the Acts of 2016, DPU 18-64, 18-65, 18-66. Massachusetts Department of Energy Resources. https://macleanenergy.files.wordpress.com/2018/07/doer-83d-filing-letter-dpu-18-64-18-65-18-66 july-23-2018.pdf

IPCC. 2018. Global warming of 1.5°C: Summary for policymakers. Intergovernmental Panel on Climate Change. https://report.ipcc.ch/sr15/pdf/sr15_spm_final.pdf

Karlsson, M, Alfredsson, E, Westling, N. 2020. Climate policy co-benefits: a review. *Climate Policy*, **20**(3), 292-316. DOI: 10.1080/14693062.2020.1724070

Larsen, K, Pitt, H, Larsen, J, Herndon, W, Houser, T, Kolus, H, Mohan, S, Wimberger, E. 2020. Taking Stock 2020. Rhodium Group. Retrieved July 9, 2020 from https://rhg.com/research/taking-stock-2020/

Lasker, T. 2017. MBTA Sustainability Report. Massachusetts Bay Transportation Authority. https://cdn.mbta.com/sites/default/files/Sustainability/sustainability-report-092617.pdf

MassDEP. 2018. Electricity sector regulations. Massachusetts Department of Environmental Protection. Retrieved June 18, 2020 from https://www.mass.gov/doc/fact-sheet-massdep-electricity-sector-regulations/download

MassDEP. 2019. Massachusetts annual greenhouse gas emissions inventory: 1990-2017, with partial 2018 data. Massachusetts Department of Environmental Protection. https://www.mass.gov/doc/appendix-c-massachusetts-annual-greenhouse-gas-emissions-inventory-1990-2017-with-partial-2018/download

MassDEP. 2020. 7.75 Clean Energy Standard. In 310 CMR (Code of Massachusetts Regulations): Department of Environmental Protection. p. 513. Retrieved June 24, 2020 from https://www.mass.gov/doc/310-cmr-700-air-pollution-control-regulations/download

NCSL. 2020. State renewable portfolio standards and goals. National Conference of State Legislators. Retrieved June 16, 2020 from https://www.ncsl.org/research/energy/renewable-portfolio-standards.aspx

Rosenberg, J, Toder, E, Lu, C. 2018. Distributional implication of a carbon tax. Urban-Brookings Tax Policy Center and Columbia Center of Global Energy Policy. https://energypolicy.columbia.edu/sites/default/files/pictures/CGEP_Distributional_Implications_CarbonTax.pdf

TCI. 2010. Declaration of Intent. Transportation and Climate Initiative. https://www.transportationandclimate.org/sites/default/files/TCI-declaration.pdf

TCI. 2019a. Framework for a draft regional policy proposal. Transportation and Climate Initiative. https://www.transportationandclimate.org/sites/default/files/TCI-Framework_10-01-2019.pdf

TCI. 2019b. Webinar: Draft memorandum of understanding & 2019 cap-and-invest modeling results. Transportation and Climate Initiative. https://www.transportationandclimate.org/sites/default/files/TCI Public Webinar Slides_20191217.pdf

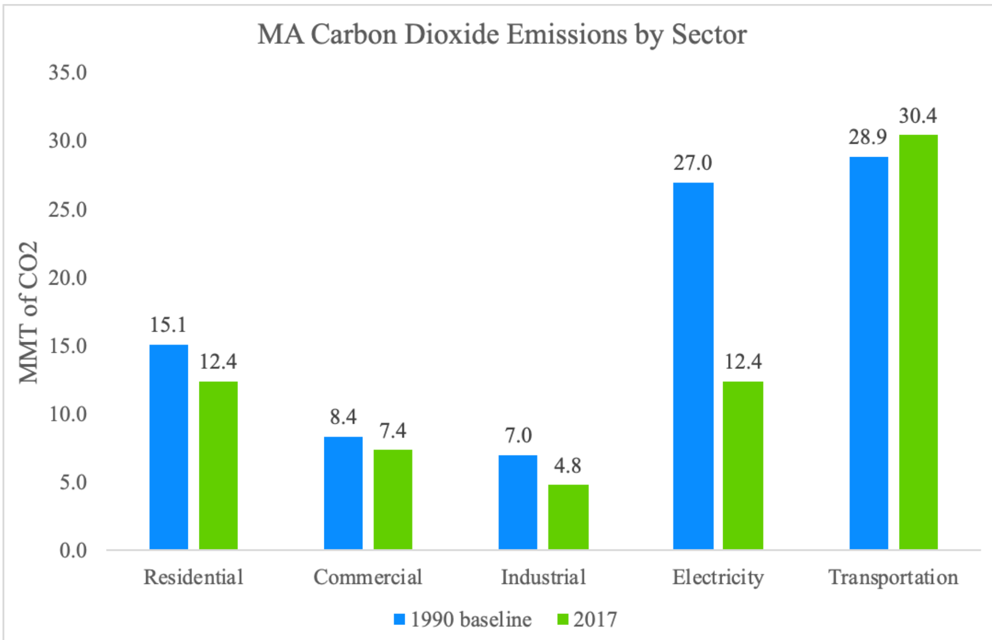
UC Berkeley. 2020. 2035 Report: Plummeting solar, wind, and battery costs can accelerate our clean energy future. University of California Berkeley. https://www.2035report.com/

UMass Donahue Institute. 2019. Annual building permit data, 200-2018. Massachusetts State Data Center. http://www.donahue.umassp.edu/business-groups/economic-public-policy-research/massachusetts-state-data-center

USGBC. 2019. Zero energy buildings in Massachusetts: Saving money from the start. US Green Building Council Massachusetts. https://builtenvironmentplus.org/zero-energy-buildings/

## Appendix A: Summary of Emissions by Sector

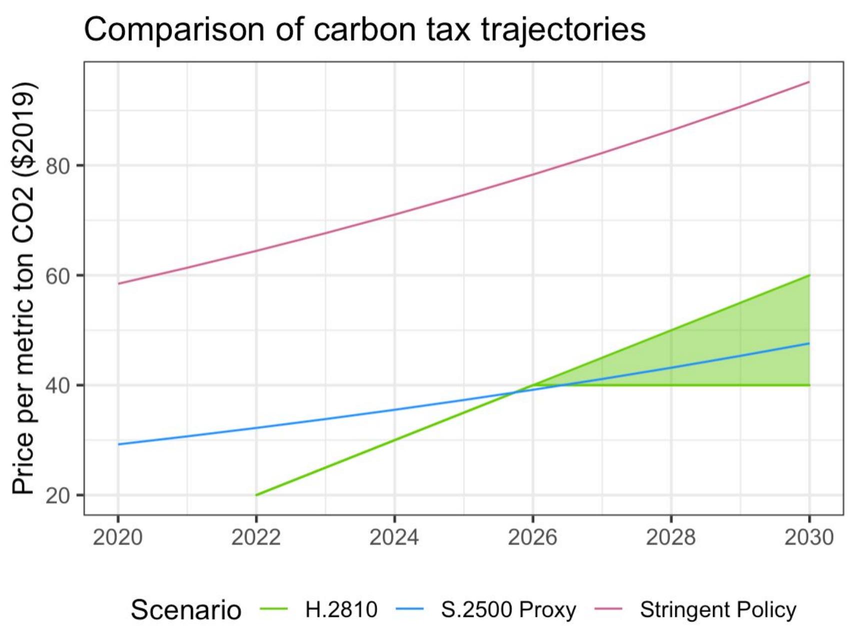
The Massachusetts Department of Environmental Protection publishes yearly greenhouse gas inventory data for the state (MassDEP, 2019). We included emissions from both in-state generation and imported power in the electricity sector and placed municipal waste combustion in the industrial sector. Although electricity is consumed by all the sectors, electricity-related emissions are only included in the power sector to prevent double counting. Emissions from greenhouse gases other than carbon dioxide are covered by S.2500's net zero goal but are not included in our analysis. These gases include methane (from natural gas leaks, landfills, and wastewater), nitrous oxide (transportation, agriculture), and fluorine gases (semiconductor manufacture and substitutes for ozone-depleting substances).



## Appendix B: Detailed Methods

**Price trajectory:** The implementation of carbon pricing would be the major source of emissions reductions under S.2500. Since the bill does not specify a price trajectory, we used other recent bills to determine a likely price. H.2810, "An Act to promote green infrastructure and reduce carbon emissions," was co-signed by over 100 Representatives and would set a tax that begins at \$20/MT $CO_2e$ (\$2019) and rises \$5 a year until it reaches \$40. In subsequent years, it continues increasing only if the state is in nonattainment of its emissions target (Bill H.2810, 2019). The green region on the graph below shows this range of values.

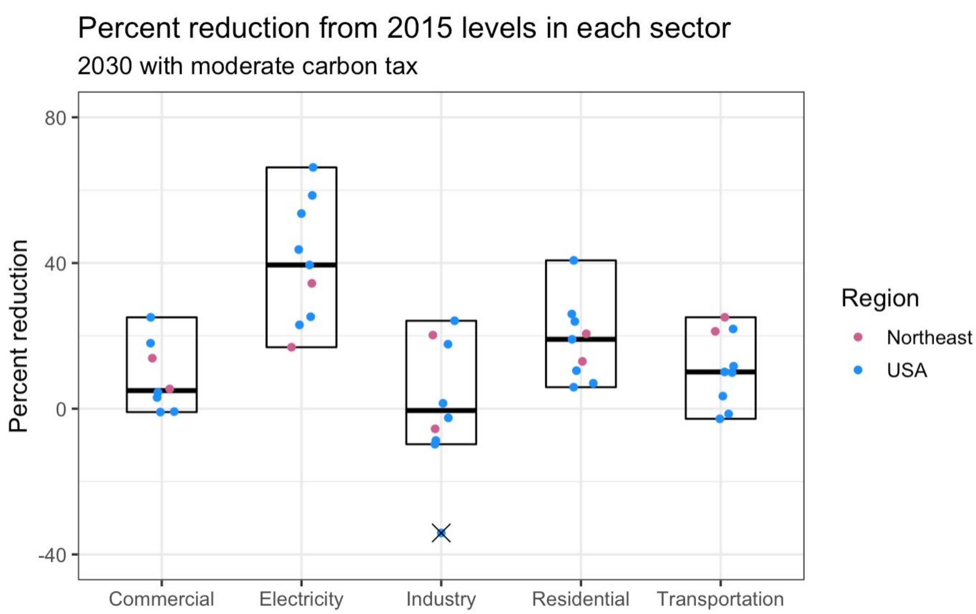
In our analysis, we estimated the effect of a moderate tax resembling H.2810 with a \$25 tax that rises 5% a year (\$2010) that is represented in EMF modeling. In 2019 dollars, that is \$29/MT $CO_2$ in 2020 and \$48/MT $CO_2$ in 2030. This trajectory, which we used in the S.2500 proxy case, is shown in blue on the graph. In the stringent policy case, we used the EMF scenario of a \$50 tax rising at 5% a year (\$2010). In 2019 dollars, this tax begins at \$58/MT in 2020 and reaches \$95 in 2030.



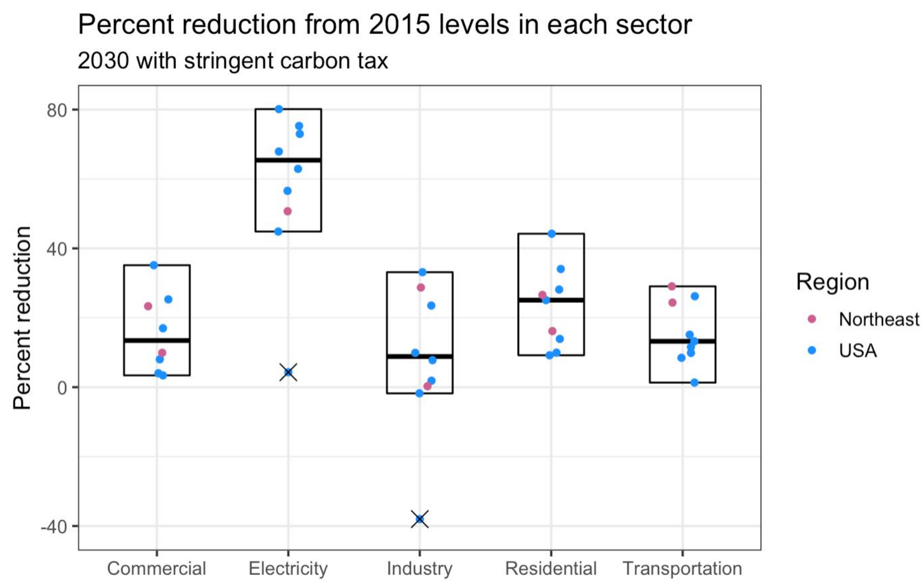

**Applying EMF data to MA emissions:** The EMF data contains projections from multiple economic models run at the national (and sometimes regional) scale, helping to avoid bias specific to individual models. Each carbon tax scenario also includes a variety of revenue neutral recycling methods. Because the use of revenue does not significantly affect emissions reductions (Barron et al. 2018), we averaged them together. Only three models ran scenarios specific to the Northeast (no models reported MA-specific results). Since the regional results were not clearly different from the whole USA projections, we decided to use data from both regions in order to include a wider range of models (for 7 models total). Applying these national and regional level projections to a single state assumes that they will respond in a similar fashion, which makes this an admittedly approximate exercise. National-level results would be clearly inappropriate for the electricity sector, as Massachusetts has a significantly lower carbon intensity than many parts of the country. For the other sectors, the use of fossil fuels and nature of the infrastructure is more broadly similar and can serve as a rough proxy in the absence of a detailed and current state-specific model.

We calculated the percent change in emissions from 2015 to 2030 in each sector and model under the two trajectories. Although the EMF carbon tax begins in 2020, we calculated the percent change from 2015, because price anticipation causes significant emissions reductions before the tax is actually implemented in some models. We recorded the maximum, median, and minimum response in each sector for both tax scenarios and applied these percentages to 2015 Massachusetts emissions in the residential, commercial, and industrial sectors to calculate projected 2030 emissions.

The graphs below show emission reductions from 2015–2030 for the models in the EMF dataset. The reductions are shown as percentages of 2015 levels. Crossed-out points are outliers that were not included in the analysis. The black crossbars show maximum, minimum, and median percent reduction in each sector. Note that while electricity and transportation are shown on the graphs, we did not use the EMF carbon tax data for these sectors in our analysis.




*Reductions from 2015 to 2030 for models in the EMF dataset under the moderate carbon tax. Reductions are shown as percentages of 2015 levels. The crossed out point is an outlier, possibly caused by a model reporting error, that was excluded from our analysis. The black crossbars show maximum, minimum, and median percent reduction in each sector.*




*Reductions from 2015 to 2030 for models in the EMF dataset under the stringent carbon tax. Reductions are shown as percentages of 2015 levels. The crossed out points are outliers, possibly caused by model reporting errors, that were excluded from our analysis. The black crossbars show maximum, minimum, and median percent reduction in each sector.*

## Appendix C: Projected Results of TCI

**TCI modeling:** The chart below shows projected results of the TCI cap and invest program. For our analysis, we assumed that Massachusetts would implement the 25% cap reduction case, which is the most stringent option. As the table shows, the program would have significant public health benefits as well as reducing emissions (TCI, 2019b).

| | No Cap No Investments | | 20% Cap Reduction with Investments | | 22% Cap Reduction with Investments | | 25% Cap Reduction with Investments | |
|---|---|---|---|---|---|---|---|---|
| | Reference Case | | Policy Case | | Policy Case | | Policy Case | |
| | 2022 | 2032 | 2022 | 2032 | 2022 | 2032 | 2022 | 2032 |
| **Emissions** Total, million metric tons; and percent reduction from 2032 to 2022 | 254 | 206 **-19%*** | 254 | 202 **-20.5%** | 254 | 199 **-22%** | 253 | 192 **-24%** |
| **Allowance Prices** per metric ton (2017$) | *n/a* | *n/a* | $6 | $9 | $11 | $18 | $22 | $36 |
| **Total Proceeds** (Billion/ year) | *n/a* | *n/a* | $1.4 | $1.8 | $2.8 | $3.6 | $5.6 | $6.9 |
| **Public Health Benefits,** *Prelim.* (Billions of 2017$) | *n/a* | *n/a* | - | $3 | - | $6 | - | $10 |
| **Avoided Climate Impacts** (Billions of 2017$) | *n/a* | *n/a* | - | $0.25 | - | $0.46 | - | $0.89 |

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*Reference case projections represent TCI's best estimates. Sensitivity analysis assumptions—such as a roll back of federal vehicle standards and low oil prices—could lead to $CO_2$ emission reductions of as little as 6% from 2022 to 2032. 28

**Applying TCI data to Massachusetts:** Massachusetts emissions data is available through 2017. Since the TCI cap and invest program would not begin until 2022, we estimated MA transportation emissions in 2022 using the EIA's 2020 Annual Energy Outlook (AEO). From 2017–2022, non-electricity transportation emissions in the AEO New England reference case decreased by 5%. We assumed that TCI emissions reductions occur linearly between 2022 and 2032, so that 80% of the reductions in a given case occur by 2030. In the TCI reference case, emissions decrease by ~15% by 2030, and in the 25% cap reduction case, emissions decrease by ~19% by 2030. We assumed that MA emissions scale with the AEO and TCI regions, and applied these percent reductions to 2017 MA emissions in order to calculate 2030 emissions.

**Comparing TCI with EMF modeling:** Because Massachusetts has been a member of TCI since its founding in 2010 and helped to develop the cap and invest proposal, the state would likely use TCI to fulfill the requirement for a carbon price in the transportation sector (TCI, 2010; EEA, 2018). However, S.2500 does not specify how the carbon price should be implemented, so MA could choose to implement a tax instead. According to the EMF data, a moderate carbon tax would reduce transportation emissions to 22–30 MMT in 2030, with a median of 26 MMT. Under the stringent tax, model estimates span a similar range from 21–29 MMT, with a median of 25 MMT. Emissions would be 23 MMT under the TCI 25% cap reduction, which is at the lower end of the carbon tax range and is lower than both median values. Given the attention to transportation specific issues in the TCI models and the investment features that help reduce emissions, we place greater faith in the emissions reductions in the TCI modeling.

**Appendix D: Stretch code estimation**

As of November 2019, 278 municipalities containing 86% of the Massachusetts population had implemented the current stretch building energy code (DOER, 2019). The stretch code applies to new construction of residential buildings and commercial buildings over 100,000 square feet (GCD, 2017). Because we were unable to find published estimates of the impacts of these standards but recognized their importance for both short- and long-term reductions, we calculated a crude order-of-magnitude estimate.

According to building permit data from the UMass Donahue Institute, 14,300 new housing units were constructed in stretch code communities in 2018 (UMass, 2019). The average annual non-electricity emissions per New England housing unit are approximately 4.6 metric tons (EIA, 2018). To estimate emission reductions by 2030, we assumed that the net zero code would be implemented in all the towns with the current stretch code beginning in 2022. If construction continues at 2018 levels, there would be approximately 130,000 net zero residential buildings by 2030. This translates to ~0.5 MMT $CO_2$ fewer emissions. No building permit data was available for commercial buildings, so this estimate includes reductions from residential buildings only.

This calculation provides an order-of-magnitude estimate for the net zero code's effects but contains several approximations. The timing of stretch code implementation is uncertain and depends largely on how the state incentivizes its adoption. The exact rate of new construction, especially post COVID-19, is unknown. In addition, the net zero code removes emissions from new construction in towns that implement the current stretch code, so using average emissions from buildings of all ages and locations overestimates the code's impact. On the other hand, the omission of the code's coverage of large commercial buildings underestimates the code's impact. Finally, there is potentially overlap between the reductions from a building code policy and carbon prices in the residential and commercial sectors. The delay in the commercial and residential sector carbon prices in S.2500 (potentially until 2025 and 2030, respectively) led us to err on the side of including the measure. A more detailed accounting would also take building size and electricity emissions intensity into account. For the purposes of this analysis, these results simply suggest that the reductions from building codes can be significant but not sufficient to close the emissions gap to the broader policy goal.