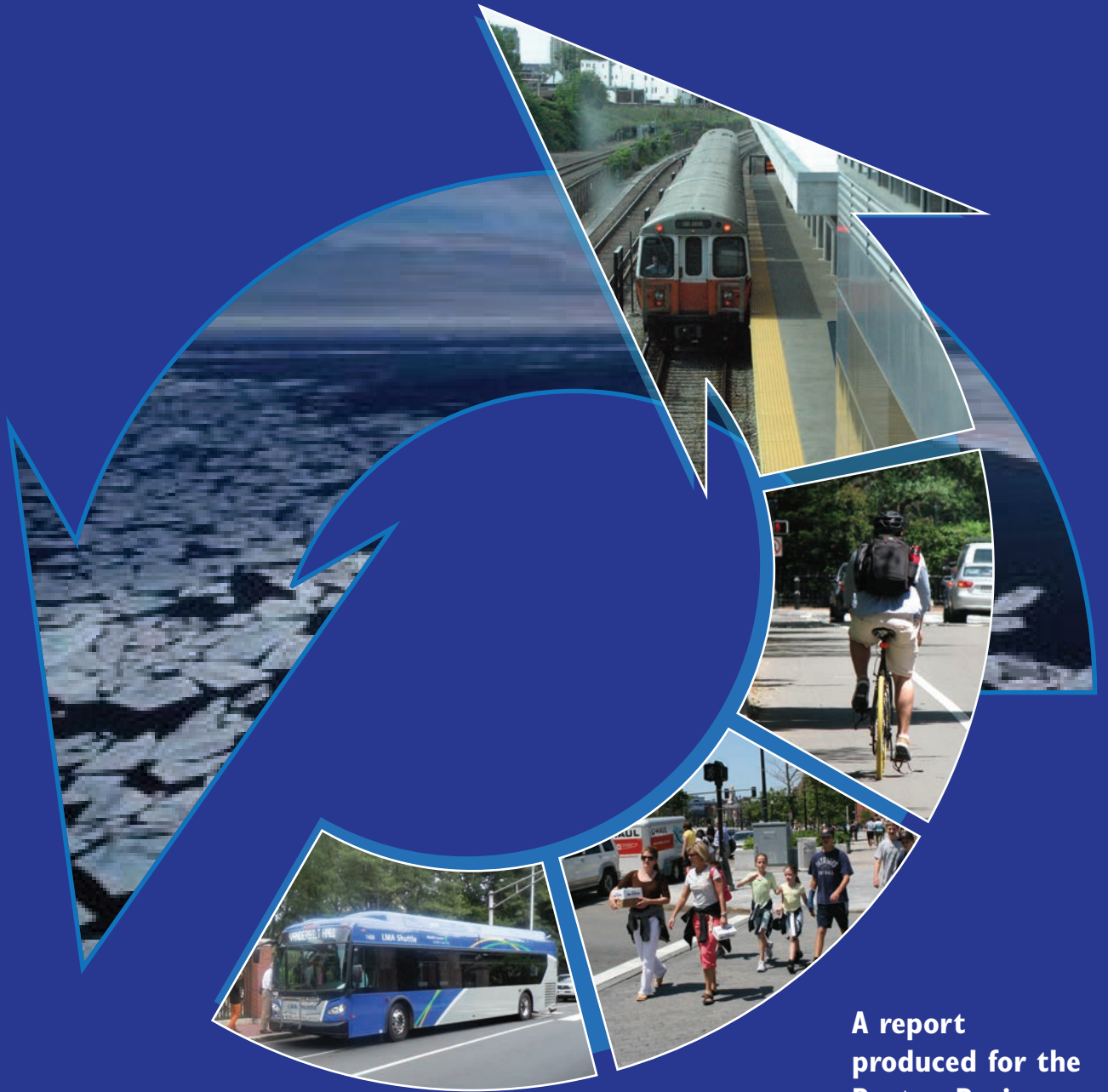# Greenhouse Gas Reduction Strategy Alternatives: Cost-Effectiveness Analysis

A report produced for the Boston Region Metropolitan Organization

Greenhouse Gas Reduction Strategy Alternatives: Cost-Effectiveness Analysis

A Report for the Boston Region MPO

Project Manager
Anne McGahan

Project Principal
Scott Peterson

Data Analysts
Matthew Archer
Katrina Crocker
William Kuttner
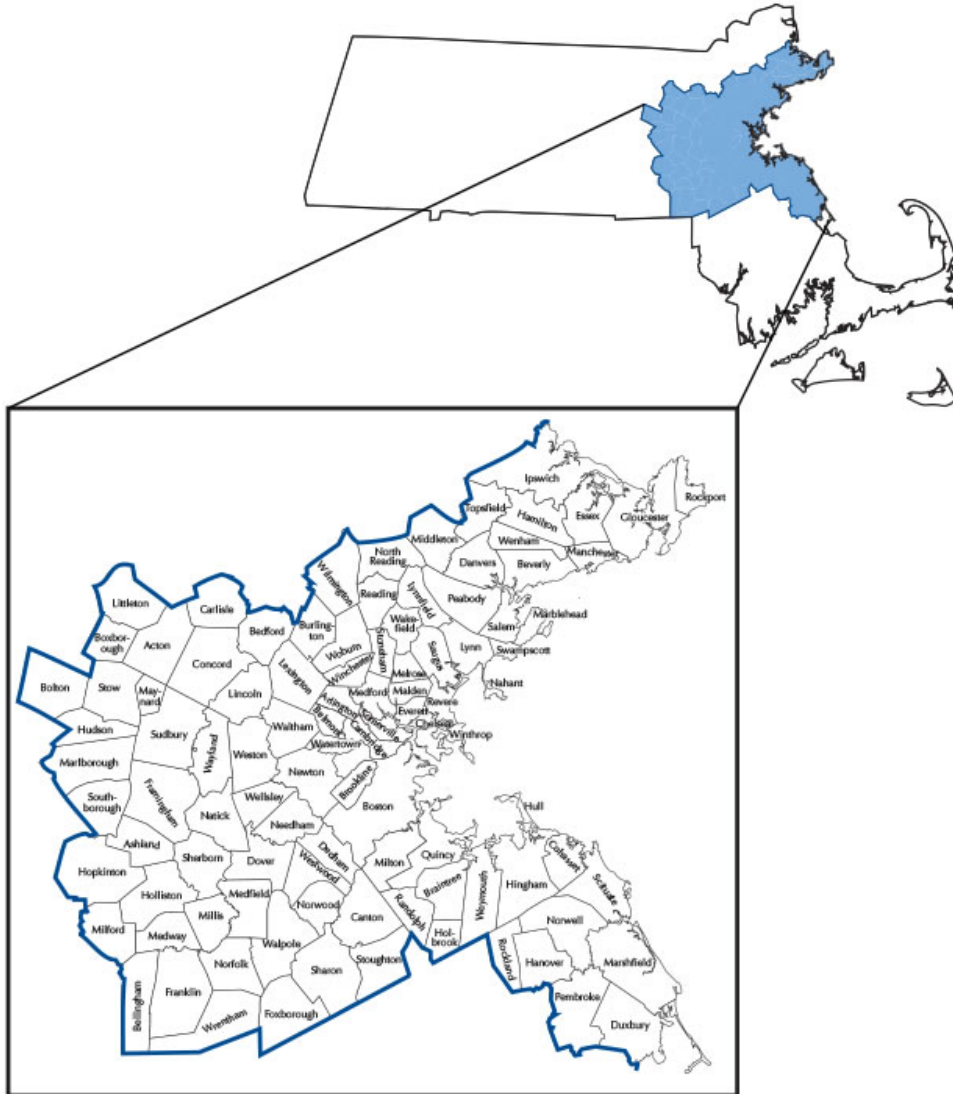Michelle Scott

Graphics
Jane Gillis
Kate Parker-O'Toole

Cover Design
Jane Gillis

January 2016

To request additional copies of this document or copies in an accessible format, contact:

Central Transportation Planning Staff
State Transportation Building
Ten Park Plaza, Suite 2150
Boston, Massachusetts 02116
(857) 702-3700
(617) 570-9192 (fax)
(617) 570-9193 (TTY)
ctps@ctps.org
www.bostonmpo.org

ABSTRACT

This report provides information about various transportation strategies that support reduction of GHG emissions. This will help the Boson Region MPO to identify transportation investments that are the most cost-effective in reducing GHG emissions. Some examples of GHG reduction strategies are projects that shift travelers from single-occupant vehicles to biking, walking, or transit.

This report includes a literature review and research into work performed by federal, state, and regional transportation agencies; universities; and advocacy and nonprofit organizations that could yield information on GHG impacts and costs of implementing various reduction strategies across all transportation modes. MPO staff inventoried past and current MPO programming within the context of these strategies and quantified the projected GHG impacts using various tools. MPO staff then calculated the cost-effectiveness of each transportation strategy and identified those strategies that are most effective at reducing GHG emissions.

In addition, this report summarizes ongoing work that will provide further information to help the MPO make informed decisions when prioritizing and funding projects, programs, and studies to reduce GHG emissions in the future. It also discusses next steps that the MPO can take to include GHG reduction as part of its decision-making process.

TABLE OF CONTENTS   PAGE

TABLE OF TABLES AND FIGURES   PAGE

Executive Summary

ES.1   MPO ROLE IN GHG REDUCTION

This study was undertaken to provide information about cost-effective greenhouse gas (GHG) reduction strategies to help the Boston Region Metropolitan Planning Organization (MPO) make informed decisions when prioritizing and funding projects, programs, and studies to reduce GHG emissions in the future. The MPO acknowledges that climate change likely will affect the Boston region significantly if climate trends continue as projected. In order to minimize the negative impacts, the MPO is taking steps to decrease our carbon footprint while simultaneously adapting our transportation system to minimize damage from natural hazards. The MPO has several tools at its disposal to support reductions in GHG emissions that are produced by the region's transportation system, including the MPO's:

- Capital-investment funds allocated through the Long-Range Transportation Plan (LRTP) and the Transportation Improvement Program (TIP)
- Planning and research funds, which are described in the Unified Planning Work Program (UPWP)
- Public outreach and involvement tools, which are supported with UPWP funds and can be used to disseminate information
- Potential role as an advocate for various transportation policies and practices

Using its vision, goals, and objectives, the MPO considers projects and strategies that protect and enhance the environment. One goal is Clean Air and Clean Communities with an objective to "reduce greenhouse gases generated in the Boston region by all transportation modes as outlined in the Global Warming Solutions Act."

ES.2   LITERATURE REVIEW

One objective of this study was to research literature about GHG-reduction strategies, in order to understand their potential to reduce greenhouse gas emissions and their cost-effectiveness in terms of implementation costs. Twenty-three strategies were identified that fall into three categories (required employer-offered compressed work week and compressed workweek: mandatory public and voluntary private are separated resulting in 24 strategies in Appendix A):

- Creating a more efficient transportation system that has lower GHG emissions
- Promoting fuel efficiency and cleaner vehicles
- Coordinating transportation with land use decisions

Of these strategies, it was determined that the MPO could support 14 either through funding in the LRTP and TIP, study through the UPWP with eventual funding for implementation in the LRTP or TIP, and publicizing through public outreach. Table ES.1 shows the 23 strategies with the MPO fundable strategies in green. Strategies that the MPO could study that are not in green would require a partnership with another agency in order to implement that strategy. Also included in the table are rankings for potential GHG reductions and the average direct cost-effectiveness of strategies for which cost information was available. The rankings of the GHG and cost-effectiveness information are outlined in section 4.2 of the report.

TABLE ES.1
Twenty-Three Promising Strategies by Type, Potential MPO Role in Implementation, and GHG and Cost-Effectiveness Ranking
(Based on National Data)

Category	Strategy	Strategy Type	Potential MPO Role	GHG Ranking*	Cost Ranking**
Creating a More Efficient Transportation System that Has Lower GHG Emissions	Pedestrian Improvements	Transportation System Planning, Funding, and Design	Fund or Study	14	13
	Bicycling Improvements	Transportation System Planning, Funding, and Design	Fund or Study	19	12
	Workplace Transportation Demand Management	Travel Demand Management	Fund or Study	13	9
	Teleworking	Travel Demand Management	Fund or Study	11	17
	Individualized Marketing of Transportation Services	Travel Demand Management	Fund	17	8
	Ridesharing	Travel Demand Management	Fund or Study	24	7
	Car Sharing	Travel Demand Management	Fund or Study	23	4

Category	Strategy	Strategy Type	Potential MPO Role	GHG Ranking*	Cost Ranking**
	Compressed Work Weeks	Travel Demand Management	Study	5/15	1
	Expansion of Urban Fixed-Guideway Transit	Transportation System Planning, Funding, and Design	Fund or Study	10	18
	Rail Freight Infrastructure	Transportation System Planning, Funding, and Design	Fund or Study	21	11
	Increased Transit Service	Transportation System Management and Operations	Fund or Study	12	19
	Transit Fare Reductions	Transportation System Management and Operations	Study	16	16
	Pay-As-You-Drive Insurance	Taxation and Pricing	Study or Advocate	3	6
	Vehicle-Miles-Traveled Fees	Taxation and Pricing	Study or Advocate	6	10
	Congestion Pricing	Taxation and Pricing	Study or Advocate	8	14
	Carbon Tax or Cap-and-Trade	Taxation and Pricing	Study or Advocate	1	NA
	Alternative Construction Materials	Construction Practices	Advocate	9	15
Promote Fuel Efficiency and Cleaner Vehicles	Truck-Idling Reduction	Transportation System Management and Operations	Fund or Study	18	5
	Reduced Speed Limits	Transportation System Management and Operations	Study or Advocate	7	3
	Driver Education and Eco-Driving	Public Education	Publicize	2	N/A
	Information on Vehicle Purchases	Public Education	Publicize	20	N/A

Category	Strategy	Strategy Type	Potential MPO Role	GHG Ranking*	Cost Ranking**
Coordinate Transportation with Land Use Decisions	Compact Development	Land Use Policies	Study or Advocate	4	2
	Parking Management	Land Use Policies	Fund or Study	22	NA

*GHG Ranking is from most effective to least effective in reducing GHG emissions.

**Cost Ranking is from the most cost-effective to the least cost-effective in reducing GHG emissions.

Note: Green text indicates that a strategy can be funded by the MPO.

Source: Central Transportation Planning Staff.

As shown in the table, each category is broken down into strategy type:

1. Creating a more efficient transportation system that has lower emissions
   - Transportation System Planning, Funding, and Design Transportation System Management and Operations
   - Travel Demand Management
   - Taxation and Pricing
2. Promoting fuel efficiency and cleaner vehicles
   - Transportation System Management and Operations
   - Public Education
3. Coordinate transportation with land use decisions
   - Land Use Policies

The majority of the strategies fall into "creating a more efficient transportation system" category. The pricing strategies, such as cap-and-trade or carbon tax, congestion pricing, pay-as-you-drive insurance, and VMT fee, have the most potential to reduce GHG emissions. The MPO does not have the authority to implement these programs. Thus, for these strategies, it may be appropriate to advocate for implementation to whichever local, State, or Federal body that has jurisdiction. For example, a carbon tax or cap-and-trade policy could greatly benefit greenhouse gas reduction in transportation, but would fall under national or state jurisdiction. The MPO could, however, study or advocate for the programs.

The MPO can implement a number of other strategies in this category. Infrastructure investments in transit, walking, bicycling, and rail facilities and improvements to transit service (transportation system planning, funding, and design and transportation system management and operations) are needed to strengthen low-carbon transportation choices; however, they are at the mid-to-lower end of strategies that are both GHG and cost-effective.

Many of the travel demand management strategies that the MPO could fund rank lower in GHG reduction, but many are more cost-effective than the infrastructure projects. Both the infrastructure and the travel demand management strategies should not be discounted in importance because of their smaller relative potential for reductions or lower cost-effectiveness. These strategies can affect the success of others, or are important for balancing equity and other needs of the transportation system as a whole. Some of the least-cost effective strategies, namely the transit-focused strategies and teleworking, have the ability to achieve larger reductions in total; without these strategies, larger emission reductions might not be achieved. In addition, both the transit strategies and teleworking have many other benefits that support cost expenditure, in addition to GHG reduction. These strategies have important mobility and accessibility benefits.

The MPO can publicize two of the strategies that fall under the "promoting fuel efficiency and cleaner vehicles" category. Driver education/eco-driving can play a big part in reducing greenhouse gas emissions from transportation; however, the MPO can only publicize and promote this program for its GHG benefits. The MPO could consider seeking funding partnerships to deploy driver education or eco-driving. It also could study truck-idling reduction and potentially fund the purchase of idle reduction equipment for trucks through its CMAQ program. The MPO could study the effects of implementing reduced speed limits, but this strategy would ultimately need to be enforced through the local and state police.

All strategies, in the "coordinating transportation with land use decisions" category, will require partnerships or strengthened collaboration across agencies. For instance, MAPC develops the land use plan for the region, so it is better positioned to support the compact land use strategy. Ultimately, local entities would need to implement any land use changes in their municipalities. Compact development not only has the potential to achieve the fourth-largest GHG reductions, but also could affect the strategies that the MPO can directly implement—transit infrastructure improvements and walking and bicycle facilities. This strategy highlights the benefits of the MPO/MAPC partnership.

Partnering may be advantageous for strategies that the MPO can study. For example, MAPC has already worked with communities in the Boston region to improve parking management. The MPO may be able to use its transportation expertise to support its existing work further by coordinating with MAPC to study promising parking policies under consideration so they can be implemented by municipalities.

Another example, the workplace transportation demand management and outreach campaigns and incentives strategies could benefit and expand from the existing work of MassRIDES and transportation management associations. The MPO's new Community Transportation program can help to provide CMAQ funding for startup shuttle-service operations.

Deployment of some of the greenhouse gas reduction strategies discussed in the literature review would represent change in the MPO's historical funding patterns. The MPO may consider forging new partnerships for implementation or funding of strategies. As noted in the literature review, all of the strategies could benefit from further research. Data about which strategies Massachusetts is implementing could make for better-informed decision making. Further research is needed to quantify the potential emissions reductions at the state and metropolitan regional levels.

ES.3   EVALUATION OF MPO INVESTMENTS

In developing its current LRTP, *Charting Progress to 2040*, the MPO re-evaluated its past practices and set a new course by moving away from programming expensive capital-expansion projects to ease congestion, instead setting aside more funding for small operations-and-management projects that support bicycle, pedestrian, and transit, along with fewer major roadway improvements. This is in line with greenhouse gas emissions-driven decision making. This type of funding plan is compatible with some of the strategies discussed in the literature review, especially if highway funds are flexed to transit projects.

Many of the projects that have been funded in past TIPs fall into the Intersections Improvements, Complete Streets, and Bicycle and Pedestrian improvements investment programs. Shuttle services have been funded in the past under older Suburban Mobility and Clean Air and Mobility programs—any new shuttle service projects now would fall into the new Community Transportation investment program. In the past, the MPO flexed highway funding to major infrastructure transit projects including the completed Assembly Square MBTA station and the proposed Green Line Phase II project extending the Green Line from College Avenue in Somerville to Mystic Valley Parkway in Medford.

Staff analyzed the projects that were funded or proposed for funding in past TIPs to determine their GHG and cost-effectiveness impacts. GHG emissions can be estimated using the travel demand model for highway and transit major infrastructure projects that meet capacity-adding characteristics. The majority of capacity-adding projects funded by the MPO have been analyzed as a bundle as

part of the LRTP using the travel demand model, a procedure that does not allow staff to associate a GHG reduction with a particular project. Although select major infrastructure projects have been analyzed for GHG benefits if a project-level analysis was performed by CTPS, this work used a variety of emissions factors developed through older emission models. Work that is more recent is underway; however, that work was not completed in time to include it in this report.

Given the limited availability of comparable regional model results using the same emissions model, the cost-effectiveness analysis focused on the projects that were analyzed using off-model spreadsheet analyses. The analyses included projects that were funded in the TIP under the MPO's four investment programs:

- Complete Streets
- Intersection Improvements
- Bicycle and Pedestrian Multi-Use Paths
- Shuttle Bus Services funded under the former Suburban Mobility or Clean Air and Mobility programs

For intersection and Complete Street projects, the cost per ton of GHG reduction varies widely, much more so than the construction cost per lane-mile. Projects that substantially improve a roadway's efficiency also tend to be cost-effective with a low cost per ton of GHG reduction.

The location of the project is also important. Projects located in the Inner Core and Regional Centers communities usually have higher construction costs per lane-mile than projects in the Maturing Suburbs and Developing Suburbs. However, the average tons reduction per lane-mile is greater for both the Inner Core and Regional Centers than for the Maturing and Developing Suburbs. Both of these differences may be attributed to the higher density of these more urbanized communities. Higher urban density usually implies higher construction costs as well as higher traffic volumes being funneled through inefficient roadway subsystems.

The higher average construction costs and efficiency benefit of the urbanized groups roughly balance out, and the average cost per ton of annual GHG reduction is similar for the Inner Core, Regional Centers, and Maturing Suburbs. The lower average cost-effectiveness in the Developing Suburbs may be attributable to lower traffic volumes in these communities.

Multi-use paths are used by pedestrians, bicycles, and other non-motorized vehicles. Unlike the roadway programs, GHG reductions from these projects do not reflect improved traffic efficiency. Instead, the construction of a multi-use path is assumed to make the non-motorized modes more attractive. The annual GHG reduction reflects an estimate of mode shifts away from auto across the projects.

See Table ES.2 for results of the analyses of the three investment programs.

TABLE ES.2
Projected Greenhouse Gas Reductions by Type of Investment Program
(All Costs are Thousands of Dollars)
(All Tons are Tons/Year)

Type of Program	Cost	Lane-Miles	Tons GHG	Cost per Lane-Mile	Cost per Ton	Tons per Lane-mile
Intersections	$35,804	8.88	4,813	$4,032	$7	542
Complete Streets	257,531	85.66	11,995	3,006	21	140
Multi-use Paths	41,174	21.80	1,055	1,889	39	48
All Programs	$334,509	107.46	13,050	$3,113	$26	121

Source: Central Transportation Planning Staff.

While costs and cost-effectiveness will vary widely within the three investment programs, the relationships of the program averages shown in Table ES.2 make sense intuitively. Much of the inefficiency of regional traffic is the result of obsolete and poorly designed intersections. Investing in only those lane-miles required to undertake the intersection program would reduce the most amount of GHG for the least cost. As noted in the literature review, transportation system management strategies, such as signal control management and integrated corridor management have the ability to achieve moderate GHG reductions. However, some roadway system-focused strategies have little or no ability to reduce emissions once induced demand is included the analysis.

At the opposite extreme are investments in multi-use paths. Most of the user benefits accrue to existing bicyclists and pedestrians, and the GHG reductions shown here are achieved only by attracting incremental users abandoning the auto mode.

The fourth investment program included shuttle services. Shuttle services can affect the success of other more cost-effective GHG strategies by balancing equity and other needs of the transportation system as a whole. They can offer other significant benefits including mobility, transportation equity, and livability. The service allows people who would ordinarily drive to their destination the

option to leave their car at home and use public transportation. The results of the shuttle service analysis are shown in Table ES.3 (assuming the net emissions from new shuttles and vehicle miles saved from private automobiles).

TABLE ES.3
Projected Greenhouse Gas Reductions
from MPO-Funded Shuttle Services

Sponsor	Service	Total MPO Investment	Net CO_2 Tons/Year	Initial MPO Cost/Tons per Year
MetroWest	Route 7	$43,438	42	$1,042
MetroWest	Woodland Service	139,000	147	947
Cape Ann Transportation Authority	Stage Fort	8,000	7	1,214
Acton	Dial-a-Ride	65,993	48	1,363
Acton	Park and Ride	52,993	94	561
GATRA	Franklin Service	175,655	30	5,852
GATRA	Marshfield/Duxbury Service	186,608	146	1,280
Combined		**$671,687**	**514**	**$1,307**

GATRA = Greater Attleboro-Taunton Regional Transit Authority.
Source: Central Transportation Planning Staff.

Funding this type of service is the most cost-effective to the MPO in reducing GHG when compared to the other three types of investments (Complete Streets, Intersections, and Bicycle/Pedestrian). This is because the MPO provided the startup funding for these services but the sponsors continue to support the services to realize mobility benefits, which continue to result in GHG reductions.

Finally, MassDOT performed a GHG analysis for projects that were included in its 2013−2019 Statewide Transportation Improvement Programs grouped into similar investment programs as the investment programs used by the Boston Region MPO. The only difference was that MassDOT's calculations were done over the useful life of the project, while the MPO's analysis shows the reductions for the project's first year. The useful life for highway, bicycle, and pedestrian projects was 50 years and the useful life for transit projects was 15 years.

Table ES.4 shows a comparison of statewide and MPO cost-effectiveness calculations with the projects in descending order from projects that are most cost-effective to those with a lower impact. The MPO information presented earlier in this section was revised to useful life to show a comparison with the statewide results.

TABLE ES.4
Cost-Effectiveness of Statewide and MPO Investment Programs

Investment Program	Dollars of Investment (Tons per Year)	Dollars of Investment (Over the Useful Life)
MPO Shuttle Startups	$1,307	$87
MPO Intersections	7,000	140
MA Bus Service Expansion and Bus Replacement	9,850	197
MPO Complete Streets	21,000	420
MPO Bicycle/Pedestrian	39,000	780
MA Traffic Operation Improvements	43,200	864
MA Bicycle/Pedestrian	151,550	3,031

Source: Central Transportation Planning Staff.

As shown in the table, when comparing similar investment programs between the MPO and the state as a whole, the Boston Region MPO area has a lower cost per ton, which can be attributed to Boston's greater density, and greater use of the facilities.

ES.4   ONGOING WORK

Several activities are underway at both the state and MPO level that will help the MPO in making decisions to fund the most cost-effective projects to reduce GHG emissions. These are described below.

- First-Mile and Last-Mile Transit Connections Study (MPO Initiative): As part of this study, the MPO staff is assisting municipalities, Transportation Management Associations, or other service providers that request planning support for addressing first- and last-mile connections to transit. Candidate locations are being identified through outreach to MAPC subregions and other MPO outreach activities. For identified locations, MPO staff will document existing conditions, including barriers and opportunities for linking residential, commercial, and employment areas to transit services and stations, and will propose services that could fill the gaps. Staff also may recommend improvements to support access for pedestrians and bicyclists, where applicable.

- Focus40, MassDOT's vision for MBTA's investments: MassDOT and the MBTA are in the process of developing a 25-year strategic vision for MBTA transit investments. Once completed, MassDOT and the MBTA will work with the public and stakeholders to develop and evaluate different

investment strategies to address current and future needs. This information will help the MPO to determine projects that could be funded by the MPO in later years. Transit will help the MPO to achieve its Capacity Management and Mobility goal its Clean Air and Clean Communities goal, specifically by reducing GHG.

- MassDOT Capital Investment Plan: Once the CIP is completed, the MPO will have information about projects and programs that the state will fund over the next five years. This will allow the MPO to consider projects that were not part of the CIP, and which it may want to fund under the MPO target program to help move toward its objective of reducing GHG emissions.

- MassDOT is in the process of identifying new tools and developing practices to comply with federal and state laws to assess, track, and reduce GHGs from MassDOT and MPO transportation projects.

Once this work is completed, staff will update the MPO on the outcomes of these activities.

Chapter 1—Background

1.1   THE ROLE OF GREENHOUSE GASES IN CLIMATE CHANGE

Climate change refers to any significant change in an aspect of climate—such as temperature, precipitation, or wind—that lasts for an extended period. Air temperature is affected by certain gases in the atmosphere, in which heat may become trapped and accumulate near the earth's surface, causing what is known as a greenhouse effect. A similar effect occurs in greenhouses: The glass allows the sun's rays in, but much of the heat from the rays becomes trapped inside the structure; hence the term, greenhouse gas (GHG). If atmospheric concentrations of GHGs rise, they trap heat in the lower atmosphere and gradually increase average temperatures.

Currently, the earth is experiencing rapid climate change, some of which is a result of increased human activities that cause global warming. The extraction and combustion of fossil fuels like coal, oil, and natural gas is one example of a human activity that contributes to climate change. Transportation is one of the largest sources of greenhouse gases, with motor vehicles burning gasoline and diesel and releasing GHGs such as carbon dioxide, the most common GHG. As much as one-third of GHG emissions in the United States (US) are associated with transportation.

Climate projections from the Northeast Climate Impacts Assessment (NECIA) found that, temperatures across the Northeast could increase by 2.5° Fahrenheit (F) to 4°F in winter and 1.5°F to 3.5°F in summer over the next several decades. These temperature increases will occur regardless of the emissions choices we make now because of the heat-trapping emissions released in the recent past. However, by mid-century and beyond, "today's emissions choices generate starkly different climate futures." By late this century, if global GHG emissions were reduced sharply, winters would be projected to warm by 5°F to 7.5°F and summers by 3°F to 7°F. In contrast, by late this century if GHG emissions were not reduced, winters would be projected to warm 8°F to 12°F and summers by 6°F to 14°F.[1]

---

[1] Frumhoff, P. C., et. al., *Confronting Climate Change in the U.S. Northeast*, 2007, Northeast Climate Impacts Assessment Synthesis Team, p. ix, http://www.ucsusa.org/sites/default/files/legacy/assets/documents/global_warming/pdf/confronting-climate-change-in-the-u-s-northeast.pdf.

What do these projected temperature increases mean for Massachusetts? Boston should experience a coastal flood equivalent to today's 100-year flood every two-to-four years on average by mid-century, and almost every year by the end of the century.[2] Inland areas also are at risk for more flooding, as rainfall should become more intense and more frequent. The number of heavy-precipitation events in the Northeast should increase 8 percent by mid-century and 12-to-13 percent by the end of the century.[3] Flooding can block or wash out roads and damage subway infrastructure.[4]

Transportation and Flooding

"In 1996, heavy rains raised the level of Boston's Muddy River, flooding a tunnel entrance to the 'T,' the city's subway system. The damage from this flooding closed a busy subway line for several weeks and cost the city roughly $75 million. While the main reason for this damage and disruption is simple—the tunnel entrance was not flood-proof—it also underscores the broader vulnerability of Boston's transportation infrastructure: Its subway system—the country's oldest—was not built with certain conditions in mind, including significantly higher sea levels and storm surges."[4]

The frequency of summer droughts also could increase. NECIA predicts that global warming could worsen air pollution in the Northeast, especially if GHG emissions are not reduced, creating more days when national air-quality standards cannot be met: "Deteriorating air quality would exacerbate the risk of respiratory, cardiovascular, and other ailments in … Massachusetts, which already has the highest rate of adult asthma in the United States." Higher temperatures means that people in Boston could experience double (30 days) to quadruple (60 days) the number of days each year with temperatures above 90°F, including six-to-24 days each year above 100°F; this could increase the risk of heat stroke among vulnerable populations, such as children and the elderly. However, if global greenhouse gas emissions were reduced, it would be possible to achieve the lower end of these ranges (of the number of 90°F and 100°F days) through the end of this century.[5] Ultimately, reducing GHG emissions can limit rising temperatures and prevent the worst-case effects of climate change.

---

[2] *Confronting Climate Change in the U.S. Northeast*, p. 15.
[3] *Confronting Climate Change in the U.S. Northeast*, p. 8.
[4] *Confronting Climate Change in the U.S. Northeast*, p. 22.
[5] *Confronting Climate Change in the U.S. Northeast*, p. 93.

1.2 ADDRESSING CLIMATE CHANGE

The Boston Region Metropolitan Planning Organization (MPO) has been gathering information on climate change and its effects in the Boston area since 2007. In May 2008, MPO staff published a discussion paper *Carbon Dioxide, Climate Change, and the Boston Region MPO* to inform the MPO and public about climate change issues. In 2012, staff updated this paper with new information about observed changes in climate, new policies and legislation, and new MPO initiatives that address climate change.

Concurrently, the state enacted the Massachusetts Global Warming Solutions Act (GWSA) in 2008 to create a framework for reducing greenhouse gas (GHG) emissions to levels that scientists believe would give us a chance to avoid the worst effects of global climate change, such as stronger storms, severe flooding, drought,

> **Why use units of "carbon dioxide equivalent"?**
>
> Although CO_2 is the primary type of greenhouse gas emitted by the transportation sector, other types of greenhouses gases, such as methane, nitrous oxide, and chlorofluorocarbons also are emitted. These gases have higher "global warming potential" than carbon dioxide, meaning that a ton of methane emitted, for example, contributes 28-to-36 times more to climate change than a ton of carbon dioxide. Even relatively small quantities of these other GHGs are important to take into account. Carbon dioxide equivalents (CO_2e) provide a metric that can include the effect of any GHG by comparing its warming effect to that of CO_2. In this report, any strategy's GHG reduction potential expressed in CO_2e considers not only CO_2 emissions, but also the emissions of other types of GHGs.[11]

heat waves, and disruption to ecosystems and food supplies. The Act requires reductions of GHG emissions of 25 percent from 1990 levels by 2020, and 80 percent from 1990 levels by 2050 from all sectors. Massachusetts GHG emissions in 1990 were approximately 94 million metric tons of carbon dioxide equivalents (MMTCO$_2$e).[6] As shown in Figure 1.1, the GWSA limit for 2020 would require a reduction of 23 MMTCO$_2$e, while the GWSA limit for 2050 would require a reduction of 75 MMTCO$_2$e.[7] See sidebar, "The Value of a Metric Ton of CO_2" for more information. [8]

---

[6] Massachusetts Department of Environmental Protection, Executive Office of Energy and Environmental Affairs, *Statewide Greenhouse Gas Emissions Level: 1990 Baseline and 2020 Business As Usual Projection,* 2009, http://www.mass.gov/eea/docs/dep/air/climate/1990-2020-final.pdf.

[7] Massachusetts Department of Environmental Protection, Executive Office of Energy and Environmental Affairs, *Global Warming Solutions Act 5-Year Progress Report*, 2013, http://www.mass.gov/eea/docs/eea/gwsa/ma-gwsa-5yr-progress-report-1-6-14.pdf.

[8] United States Environmental Protection Agency, GHG Equivalencies Calculator – Calculations and References, 2015, http://www2.epa.gov/energy/ghg-equivalencies-calculator-calculations-and-references.

Preliminary findings from the forthcoming update to the Commonwealth's Clean Energy and Climate Plan indicate that a reduction of GHG emissions of approximately 17 percent has been achieved through 2014.

FIGURE 1.1
Massachusetts Statewide GHG Emissions, All Sectors: 1990 Baseline and Global Warming Solutions Act 2020 and 2050 Limits
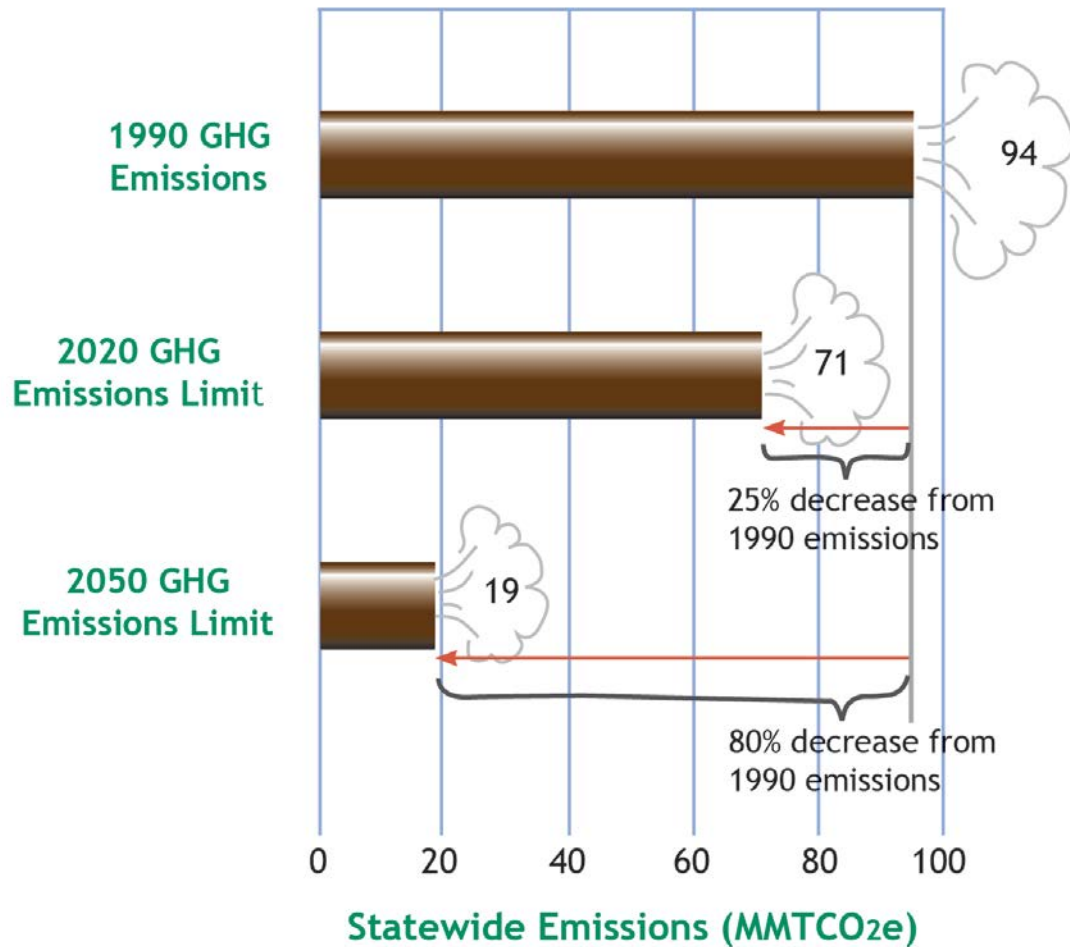
Source: Massachusetts Department of Environmental Protection, *Global Warming Solutions Act 5-Year Progress Report.*

The Value of a Metric Ton of CO_2

5.5 $MTCO_2e$ 7.3 $MTCO_2$ 3.8 $MMTCO_2$

CO_2 emissions per year
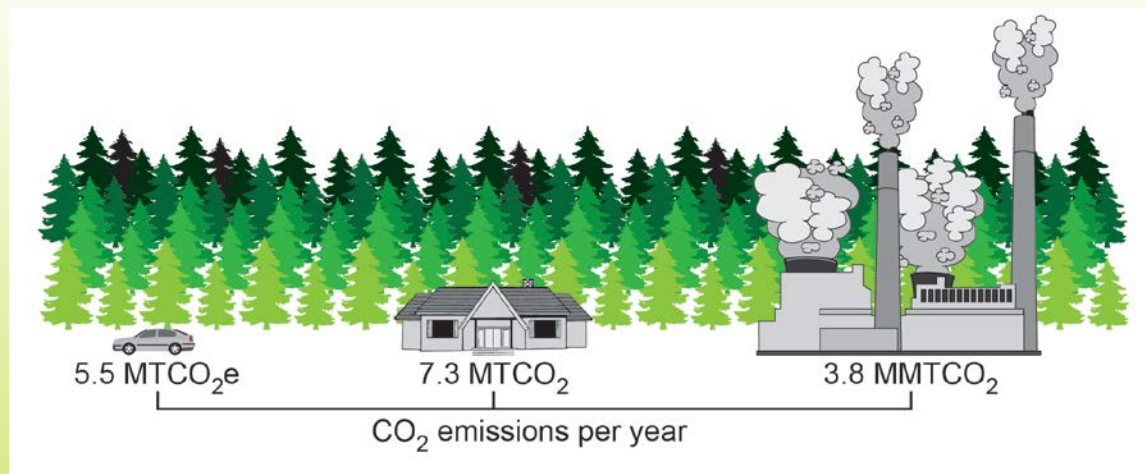
Source: Central Transportation Planning Staff.

The examples above convey a sense of the value of a metric ton of CO_2: A passenger vehicle that is driven 12,000 miles annually emits approximately 5.5 metric tons of CO_2e. Electricity used by the average home produces 7.3 metric tons of CO_2 annually. A coal-fired power plant emits 3.8 million metric tons of CO_2 each year. [8] (Please note that this diagram is not to scale)

With respect to transportation, projections based on data from the US Department of Energy and US Department of Transportation forecast substantial increases in the fuel efficiency of automobiles and light trucks between now and 2050, which will produce valuable gains in GHG reductions. These reductions, however, nearly entirely are counterbalanced by a simultaneous increase in vehicle-miles traveled (VMT) because of increases in the US population and travel. Between 2005 and 2050, a net increase in baseline GHG emissions of less than one percent is projected. [9]

Extrapolating these national trends to Massachusetts and the Boston region, achieving GHG emission reductions to GWSA levels may not be realized based on new vehicle technologies alone; the other transportation strategies discussed in the literature review (in Chapters 3 and 4 of this report) may be needed. In further examining Massachusetts VMT data after 2008, VMT has dropped below 2008 levels and is now increasing, however, at a slower rate than in the past. Further research is needed to understand if this national trend is occurring in Massachusetts.

---

[9] Cambridge Systematics, Inc., 2009, *Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions*, Urban Land Institute, p. 79-83.

To help meet the GWSA requirements, the Massachusetts Department of Transportation (MassDOT) adopted its GreenDOT policy initiative to help reduce GHG emissions by:

- Implementing travel demand management projects
- Promoting healthy transportation modes by improving pedestrian, bicycle, and public transit infrastructure
- Supporting smart-growth development by making transportation investments that enable denser, smart-growth development patterns that can support reduced GHG emissions

The responsibility of the MPO is to prioritize and fund projects, programs, and studies that help to advance its vision, goals, and objectives through its Unified Planning Work Program (UPWP), Transportation Improvement Program (TIP), and Long-Range Transportation Plan (LRTP). The MPO recently adopted its new LRTP, *Charting Progress to 2040*. As part of the LRTP's goals and objectives, the MPO adopted a goal for Clean Air and Clean Communities. One of its objectives is to "reduce greenhouse gases generated in the Boston region by all transportation modes as outlined in the Global Warming Solutions Act."

Currently, the MPO tracks the projected GHG impacts of infrastructure projects. GHG impacts are tracked at the regional level in the LRTP and at the project level in the TIP. Staff also performs a GHG and cost-effectiveness analysis for TIP projects seeking funding under the Congestion Mitigation and Air Quality Improvement Program (CMAQ). The CMAQ program provides funding for a wide range of projects that reduce transportation-related emissions, including carbon dioxide, the major contributor to climate change.

Because reducing GHG emissions is an important goal of the MPO, staff are undertaking this study to identify cost-effective GHG reduction strategies that can help inform MPO investment decisions. Some examples of GHG reduction strategies are projects that improve traffic flow, support fleet upgrades, or shift travelers from single-occupant vehicles to biking, walking, or taking transit.

This report builds on the two previous MPO papers described earlier and explores different cost-effective GHG reduction strategies that the MPO can fund or implement. Chapters 3 and 4 include a literature review and research into work performed by federal, state, and regional transportation agencies; universities; and advocacy and nonprofit organizations that could yield information on the GHG impacts and the costs of implementing various reduction strategies across all transportation modes. In Chapter 5, MPO staff inventoried past and current MPO programming within the context of these strategies and

quantified the projected GHG impacts using various tools. MPO staff calculated the cost-effectiveness of each transportation strategy to identify those strategies that would be most effective at reducing GHG emissions. Finally, Chapter 6 summarizes ongoing work that would further help the MPO to make informed decisions when prioritizing and funding projects, programs, and studies to reduce GHG emissions in the future. It also discusses next steps that the MPO can take to consider GHG as part of its decision-making process.

Chapter 2—The MPO's Role in Greenhouse Gas Reduction

2.1   MPO RESOURCES TO SUPPORT GHG REDUCTION

The optimal greenhouse gas reduction strategies for the Boston Region MPO not only will need to demonstrate cost effectiveness; they also will need to align with the MPO's roles and capabilities. The strategies discussed throughout this report should be considered in light of these roles and capabilities. The MPO has several tools at its disposal to support reductions in the GHG emissions that are produced by the region's transportation system, including the MPO's:

- Capital-investment funds allocated through the LRTP and the TIP
- Planning and research funds, which are described in the UPWP
- Public outreach and involvement tools, which are supported with UPWP funds and can be used to disseminate information
- Potential role as an advocate for various transportation policies and practices

2.1.1   MPO Capital Investment Funds

The MPO receives discretionary federal highway program funding, or Regional Target Funds, annually. This pool of discretionary funds is determined after other statewide transportation funding needs—such as those for Grant Anticipation Note (GANs) payments for the Commonwealth's Accelerated Bridge Program, Statewide Infrastructure Items, and Regional Major Infrastructure Projects—have been satisfied. MassDOT distributes these discretionary funds to the Commonwealth's 13 MPOs by formula. The Boston Region MPO's LRTP describes how the MPO plans to spend its estimated Regional Target Funds over a 25-year time horizon; and the MPO's TIP describes how the MPO would program these funds for specific projects during a 5-year period.

This discretionary federal highway program funding supports:

- Preservation and modernization of existing roadway network through resurfacing highways
- Replacement of bridges
- Reconstruction of arterial roadways
- Intersection improvements
- Off-road bicycle and pedestrian improvements

In addition, program funding may be expended on transportation projects that will improve air quality, and may be "flexed" for use on transit projects. (While the LRTP and TIP describe how Federal Transit Administration (FTA)-provided transit capital investment funds will be used in the Boston Region, the MPO can program transit projects only by using these "flexed" highway funds.)

The MPO's vision, goals, and objectives, as described in *Charting Progress to 2040*—create the framework that determines how the MPO will spend these discretionary funds. Using this framework, the MPO has established a series of investment programs. Several of the programs—including Intersection Improvements, Complete Streets, Bicycle Network and Pedestrian Connections, Community Transportation and Parking, and transit projects included in the Major Infrastructure category—relate directly to the MPO's Clean Air/Clean Communities goal. These investment programs will be supported by a series of federally designated funding programs, which are described in Table 2.1 below.

TABLE 2.1
Federal Funding Programs

Program Name	Program Description	Examples of Eligible Projects with Potential GHG Reduction Impacts [a]	Flex Funds to Transit?	Relevant MPO Investment Programs
Congestion Mitigation and Air Quality Improvement (CMAQ)	Wide range of projects in air quality nonattainment and maintenance areas for ozone, carbon monoxide, and particulate matter, that reduce transportation-related emissions	• Transit investments • Projects or programs that increase vehicle occupancy, shift travel demand to non-peak hours; or reduce travel demand (such as tele-working) • Projects or programs that improve travel flow • Non-recreational bicycle and pedestrian improvements • Public education campaigns • Alternative fuel projects (e.g., vehicle acquisitions, engine retrofits)	Yes (Includes funding for capital improvement, vehicle procurement and as many as three years' operations assistance)	• Complete Streets • Intersection Improvements • Major Infrastructure Projects (including Highway Funds Flexed to Transit) • Community Transportation • Bicycle/Pedestrian Program
Surface Transportation Block Grant Program (STBGP)	Broad range of surface transportation capital needs, including roads; transit, sea, and airport access; and vanpool, bicycle, and pedestrian facilities	• Congestion pricing projects and strategies • Construction, reconstruction, rehabilitation, resurfacing, restoration, preservation, or operational improvements for highways • Capital and operating costs for traffic monitoring, management and control facilities and programs, including advanced truck stop electrification • Carpool projects, fringe and corridor parking facilities and programs, including electric and natural gas vehicle charging infrastructure, bicycle transportation and pedestrian walkways, and accessible sidewalk modification • Transit capital costs	Yes, e.g., Green Line Extension Project (Phase 2), College Avenue to Mystic Valley Parkway/Route 16)	• Complete Streets • Intersection Improvements • Major Infrastructure Projects (including Highway Funds Flexed to Transit) • Community Transportation • Bicycle/Pedestrian Program
Highway Safety Improvement Program (HSIP)	Implementation of infrastructure-related highway safety improvements	• Traffic controls and warning devices • Intersection safety improvements • Railway-highway crossing safety features • Safety improvements for bicyclists, pedestrians, and other forms of non-motorized transportation	No	• Complete Streets • Intersection Improvements • Major Infrastructure Projects

Program Name	Program Description	Examples of Eligible Projects with Potential GHG Reduction Impacts [a]	Flex Funds to Transit?	Relevant MPO Investment Programs
National Highway Performance Program (NHPP)	Improvements to interstate routes, major urban and rural arterials, connectors to major intermodal facilities, and the national defense network. Also includes replacing or rehabilitating any public bridge, and resurfacing, restoring, and rehabilitating routes on the Interstate Highway System	• Construction, reconstruction, resurfacing, restoration, rehabilitation, preservation, or operational improvements of national highway system (NHS) segments • Construction of publicly owned intra- or inter-city bus terminals servicing the National Highway System • Bicycle transportation and pedestrian walkways	Yes	• Major Infrastructure Projects
Discretionary Funding	Specific projects included annual appropriations that are funded through grant programs such as the Transportation, Community, and System Preservation Program; Value Pricing Pilot Program; and Transportation Infrastructure Finance and Innovation Act Program.	• Dependent on specific project or program	Dependent on specific project or program	

Additional eligible projects information may be found at:

CMAQ – http://www.fhwa.dot.gov/map21/guidance/guidecmaq.cfm

HSIP – http://safety.fhwa.dot.gov/hsip/resources/fhwasa09029/sec5.cfm

NHPP – http://www.fhwa.dot.gov/map21/factsheets/nhpp.cfm

STP – http://www.fhwa.dot.gov/map21/factsheets/stp.cfm

TAP – http://www.fhwa.dot.gov/map21/guidance/guidetap.cfm

Source: Central Transportation Planning Staff.

2.1.2 MPO Planning Funds

MPOs receive metropolitan planning funds from the Federal Highway Administration (FHWA) and the FTA in order to provide for a continuing, comprehensive, and cooperative (3-C) transportation planning process in their regions. Like the MPO's capital investment funds, these funds are distributed by MassDOT to the Commonwealth's 13 MPO regions. In the Boston Region, the Central Transportation Planning Staff (CTPS) receives approximately 80 percent of these funds, while the Metropolitan Area Planning Council (MAPC) receives the other 20 percent. The MPO's plan for expending these funds is documented in the UPWP.

The Boston Region MPO uses these metropolitan transportation-planning funds to satisfy 3C planning process requirements, including, but not limited to
1. Developing the LRTP, TIP and UPWP
2. Supporting public participation in the transportation planning process
3. Conducting performance-based planning
4. Ensuring conformity with air quality requirements

MPOs also use these funds to conduct corridor, safety, and other planning studies; collecting data; monitoring trends; and studying a variety of demographic, land use development, transportation, and environmental factors. CTPS and MAPC use these planning funds to provide technical assistance to municipalities, transportation agencies, and other organizations, as well as to conduct independent studies. Through data requests, the funding can support research at local universities to understand the impacts of GHG emissions and climate change. While these funds must be used for planning activities that relate to the region's transportation system, they are flexible and may be used as tools for finding ways to reduce transportation-related GHG emissions. For example, these funds may support feasibility studies of new bicycle and pedestrian connections, transit services, travel demand management (TDM) strategies or other GHG-emission-reduction policies.

2.1.3 MPO Public Outreach and Involvement Tools

The MPO maintains various lines of communication to keep interested parties informed about and involved in the Boston region's metropolitan transportation-planning process, including:
- MPO and MPO committee meetings, Regional Transportation Advisory Council meetings, and MPO-sponsored events
- Online resources, including the MPO's website, Twitter feed, and email distribution list (MPO info)
- The MPO's bimonthly newsletter, *TRANSreport*

While these channels are used primarily for MPO business, they also could be used to communicate educational information about ways that travelers can reduce transportation-related greenhouse gas emissions. They also can announce the availability of transportation programs, projects, and resources—whether MPO funded or not—that may reduce greenhouse gas emissions.

In some cases, information and education campaigns pertaining to the connections between transportation choices, congestion, and air quality can be supported using CMAQ funds.

2.1.4 MPO Advocacy and Partnerships

If an existing or potential greenhouse gas reduction policy, program, or project falls outside of the MPO's purview, the MPO may choose to advocate on behalf of such a policy to the relevant body, such as MassDOT, the Massachusetts Bay Transportation Authority (MBTA), the Commonwealth's State Legislature or Governor, federal agencies, or national organizations.

Chapter 3—Literature Review

3.1   LITERATURE RELEVANT TO THIS STUDY

As awareness of the dangers posed by climate change widens, numerous studies have examined different strategies to reduce greenhouse gas emissions. Staff reviewed a number of these reports and found that those comparing strategies that use the same criteria offered the most applicable information. These studies include:

- *Incorporating Greenhouse Gas Emissions into the Collaborative Decision-Making Process*, a Transportation Research Board (TRB) of the National Academies, Strategic Highway Research Program (SHRP2) study, by PB Americas, Inc., Cambridge Systematics, Inc., E. H. Pechan & Associates, Inc., and EuQuant, Inc., Report S2-C09-RR-1 (Washington, D.C.), 2013
- *Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions*, an Urban Land Institute (Washington, D.C.) study, by Cambridge Systematics, 2009
- *Transportation's Role in Role in Reducing U.S. Greenhouse Gas Emissions*, a U.S. Department of Transportation (Washington, D.C.) report to Congress, by Cambridge Systematics, Inc. and Eastern Research Group, Inc., 2010
- *Reference Sourcebook for Reducing Greenhouse Gas Emissions from Transportation Sources*, US Department of Transportation, Federal Highway Administration, by Rand Corporation and RSG Inc., 2012

In addition, *Reducing Greenhouse Gas Emissions from Transportation, Opportunities in the Northeast and the Mid-Atlantic,* was released in November 2015, by the Georgetown Climate Change Center as part of the Transportation Climate Initiative (TCI). The TCI, of which Massachusetts is a member, is a collaboration of 12 Northeast and Mid-Atlantic jurisdictions committed to working together to develop a clean-energy economy and reduce greenhouse gas emissions in the transportation sector. Cambridge Systematics, an author of *Moving Cooler,* contributed the quantitative aspects of the report. It is also important to note that the Massachusetts Executive Office of Energy and Environmental Affairs is in the process of updating its Clean Energy and Climate Plan for 2020. The revised information will be available upon its release.

Greenhouse gas-reducing strategies for the transportation sector may be divided into eight categories, as follows:

1. Transportation System Planning, Funding and Design
2. Construction and Maintenance Practices
3. Transportation System Management and Operations
4. Land Use Codes, Regulations, and Policies
5. Taxation and Pricing
6. Travel Demand Management
7. Public Education
8. Vehicle and Fuel Improvements

Table 3.1 below lists the eight categories of strategies that were identified in this literature review. It also cites briefly the results of the literature review discussions. For example, strategies that show promise for reducing GHG emissions are discussed in Section 3.3 of this report, while strategies that may have a questionable impact on GHGs are discussed in Section 3.5. The GHG reduction potential of Vehicle and Fuel Improvements strategies—low carbon fuels, advanced-vehicle technologies, and vehicle air-conditioning systems—are not covered in this literature review. These three strategies already are factored into the GHG baselines in various reports.[10] The MPO does not have the authority to implement or ability to influence these strategies.

TABLE 3.1
Types of GHG Reduction Strategies
with Literature Review Classification

Category	Identified Strategy	Literature Review Discussion Results
Transportation System Planning, Funding, and Design	Expansion of urban fixed-guideway transit	Promising strategy
	Pedestrian improvements	Promising strategy
	Bicycle improvements	Promising strategy
	Rail freight infrastructure	Promising strategy
	National top 100-to-200 bottleneck relief	Questionable strategy
	Capacity expansion	Questionable strategy
Construction and Maintenance Practices	Alternative construction materials	Promising strategy
Transportation System Management and Operations	Transit fare reductions	Promising strategy

---

[10] Cambridge Systematics, 2009, *Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions*, Urban Land Institute, Washington, D.C., p. 19.

Category	Identified Strategy	Literature Review Discussion Results
	Increased transit service	Promising strategy
	Truck idling reduction	Promising strategy
	Reduced speed limits	Promising strategy
	Traffic management	Questionable strategy
	Ramp metering	Questionable strategy
Land Use Codes, Regulations, and Policies	Compact development	Promising strategy
	Parking management	Promising strategy
Taxation and Pricing	Carbon tax or cap-and-trade	Promising strategy
	Pay-as-you-drive insurance	Promising strategy
	Vehicle miles traveled fees	Promising strategy
	Congestion pricing	Promising strategy
Travel Demand Management	Workplace travel demand management (TDM) (general)	Promising strategy
	Teleworking	Promising strategy
	Compressed work weeks	Promising strategy
	Individualized marketing	Promising strategy
	Ridesharing	Promising strategy
	Car sharing	Promising strategy
Other Public Education	Driver education/eco-driving	Promising strategy
	Information on vehicle purchase	Promising strategy
Vehicle and Fuel Improvements	Advanced-vehicle technologies	Factored into GHG baselines
	Vehicle air-conditioning systems	Factored into GHG baselines
	Low carbon fuels	Factored into GHG baselines

Note: Strategies that show promise for reducing GHG emissions are discussed in Section 3.3 of this report. Strategies that may have a questionable impact on GHGs are discussed in Section 3.5.

Sources: Cambridge Systematics, Moving Cooler and Transportation Research Board, Incorporating Greenhouse Gas Emissions.

3.2   STRATEGY SELECTION CRITERIA

Staff used three main criteria to evaluate identified GHG emissions-reduction strategies:

- Greatest potential to reduce greenhouse gas emissions (assuming maximum level of deployment and successful implementation)
- Cost-effectiveness in terms of direct implementation costs
- Other considerations, including equity and social benefits or concerns, implementation feasibility, and potential MPO roles

3.2.1 Strategies' Potential to Reduce GHG Emissions

3.2.1.1 Quantifying the Strategies' Potential

For this literature review, a strategy's potential to reduce greenhouse gas emissions is quantified by percentage of reduction in transportation sector greenhouse gas emissions in 2030. This year was chosen because the primary source of this information was the Transportation Research Board report *Incorporating Greenhouse Gas Emissions into the Collaborative Decision-Making Process*, which examined the potential of various strategies to reduce GHG emissions compared to a 2030 baseline. Emissions impacts in 2050 are discussed in some cases where they greatly differ from 2030 impacts. The percentages provided are based a national level of implementation, since state- and region-specific data are not widely available. On occasion, GHG reductions are expressed in terms of million metric tons carbon dioxide equivalent (MMTCO$_2$e) in addition to percentages.[11]

Staff selected the strategies listed because they have a maximum potential to reduce national transportation GHG emissions of at least 0.2 percent compared to the 2030 baseline. Additional GHG reduction strategies exist, but they were excluded from this literature review if they do not have a maximum potential to reduce national emissions of at least 0.2 percent. A strategy's potential is considered "high" if it can reduce GHG by a maximum of at least one percent; "low" if it can reduce GHG by less than one-half percent; and "medium" if it can reduce GHG between one and one-half percent.

Although national emissions data were used in this report because of lack of state- or region-specific data for the strategies, we caution that the relative reductions that a strategy can achieve at the national level may be significantly different at state and regional levels. For instance, strategies such as bicycle and pedestrian improvements may yield the greatest emissions reductions in areas with relatively greater land use density, where trips between origins and destinations are relatively short. Because Massachusetts and the Boston region have greater population and employment densities than the rest of the country, bicycle and pedestrian improvements may be able to achieve relatively high

---

[11]US Environmental Protection Agency, 2015, *Understanding Global Warming Potentials*, http://www3.epa.gov/climatechange/ghgemissions/gwps.html.

GHG emissions reductions compared to the country as a whole. Congestion pricing is another example of a strategy that may have a relatively higher impact on GHG emissions in the Boston region than the nation as a whole, as it can be implemented only in certain congested locations. *Moving Cooler* states: "Of course, in the context of the regions in which congestion pricing is implemented (versus this study's national perspective), the relative impact on GHGs will be greater."[12] In order to understand fully the effects of implementing GHG reduction strategies in the Boston region, studies are needed to develop region-specific data for each strategy. In the meantime, national data is the best information available.

The *Moving Cooler* report cited above provides a context for national transportation emissions levels over time, which may be considered in light of GWSA limits for emissions reductions below 1990 levels.

The national transportation GHG emissions 1990 baseline was about 1,150 MMTCO$_2$e. Between 1990 and 2005, the baseline for the national transportation sector increased roughly 40 percent to about 1,650 MMTCO$_2$e. Looking forward, between 2005 and 2050 the baseline remains largely the same. *Moving Cooler* projects a net increase in baseline GHG emissions between 2005 and 2050 of less than one percent (including predicted increases in both VMT and fuel efficiency), with emissions declining from their peak in 2010. The difference between the 2005 and 2030 baseline is about three percent.[13] In order to reduce GHG emissions to GWSA targets below 1990 levels, the increases that took place between 1990 and 2005 need to be cut, in addition to the target cuts from 1990 levels. Figure 3.1 below shows the national emissions baseline for 1990, 2005, and beyond.

---

[12] Cambridge Systematics Inc., *Moving Cooler*, p. 40.
[13] Cambridge Systematics, *Moving Cooler*, pp. 79-83.

FIGURE 3.1
National Transportation GHG Baseline: 1990, 2005, and Beyond
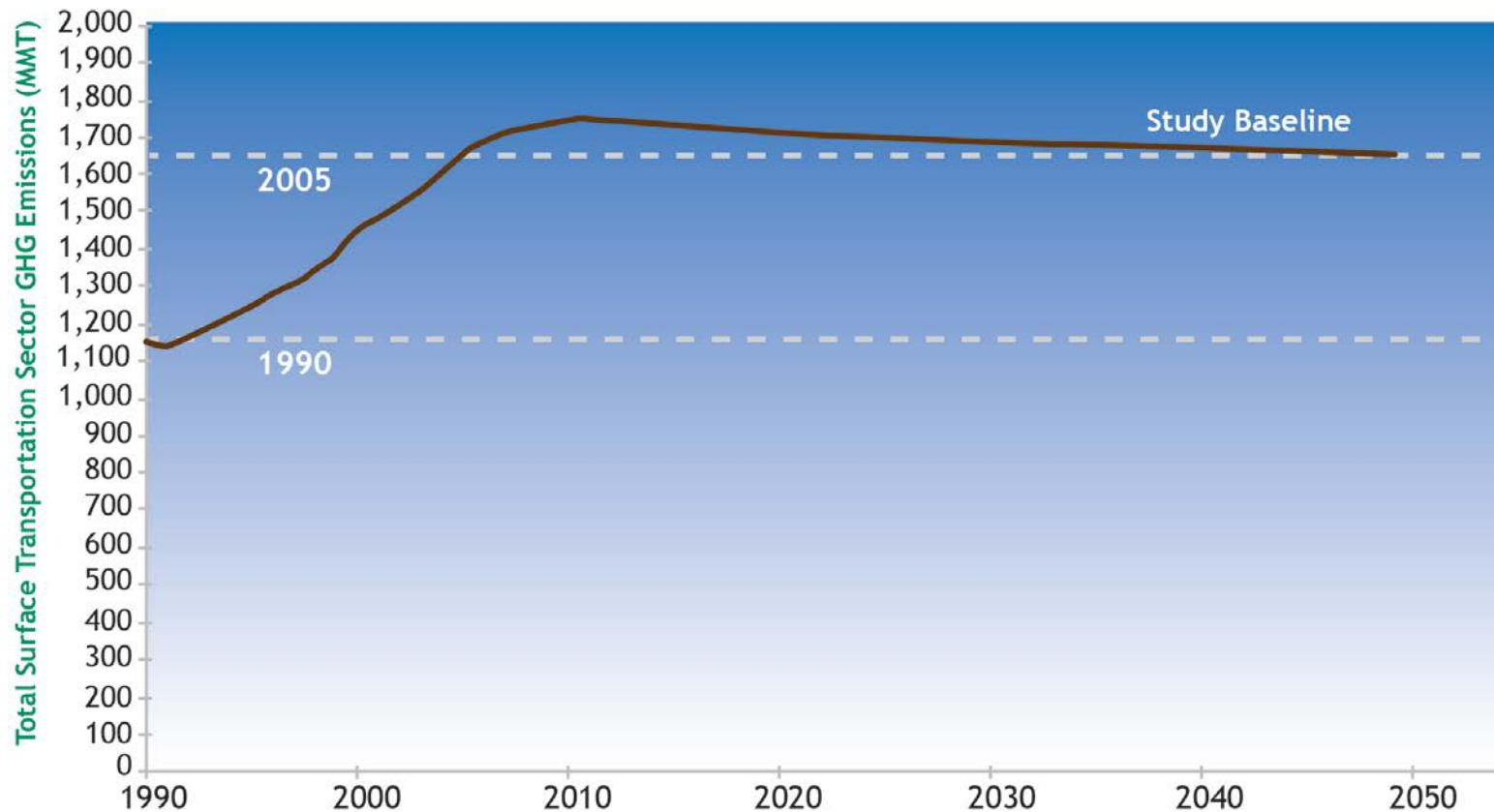
1990 and 2005 GHG Emissions - Combination of DOA AEO data and EPA GHG Inventory data
Study Baseline - Annual 1.4 percent VMT growth combined with 1.9 percent growth in fuel economy

AEO = Annual Energy Outlook. DOE = Department of Energy. VMT = vehicle miles traveled.
Source: Cambridge Systematics, *Moving Cooler.*

In Massachusetts the emissions baseline increased less between 1990 and 2005 when compared to the national level, so Massachusetts has proportionally less emissions to cut to get to below 1990 levels. Figure 3.2 below, shows GHG emissions from surface transportation in Massachusetts between 1990 and 2010. The figure indicates that greenhouse gas emissions from surface transportation in Massachusetts increased about 13 percent between 1990 and 2005, a smaller increase than the roughly 40 percent increase in GHG emissions at the national level.[14]

In Figure 3.2, emissions appear to stay the same or decrease between 2005 and 2010. While no business-as-usual baseline has been projected yet for the Massachusetts transportation sector through 2030, data through 2012 show Massachusetts emissions have remained at 2005 levels thus far.

FIGURE 3.2
Massachusetts Surface Transportation GHG Emissions, 1990–2010
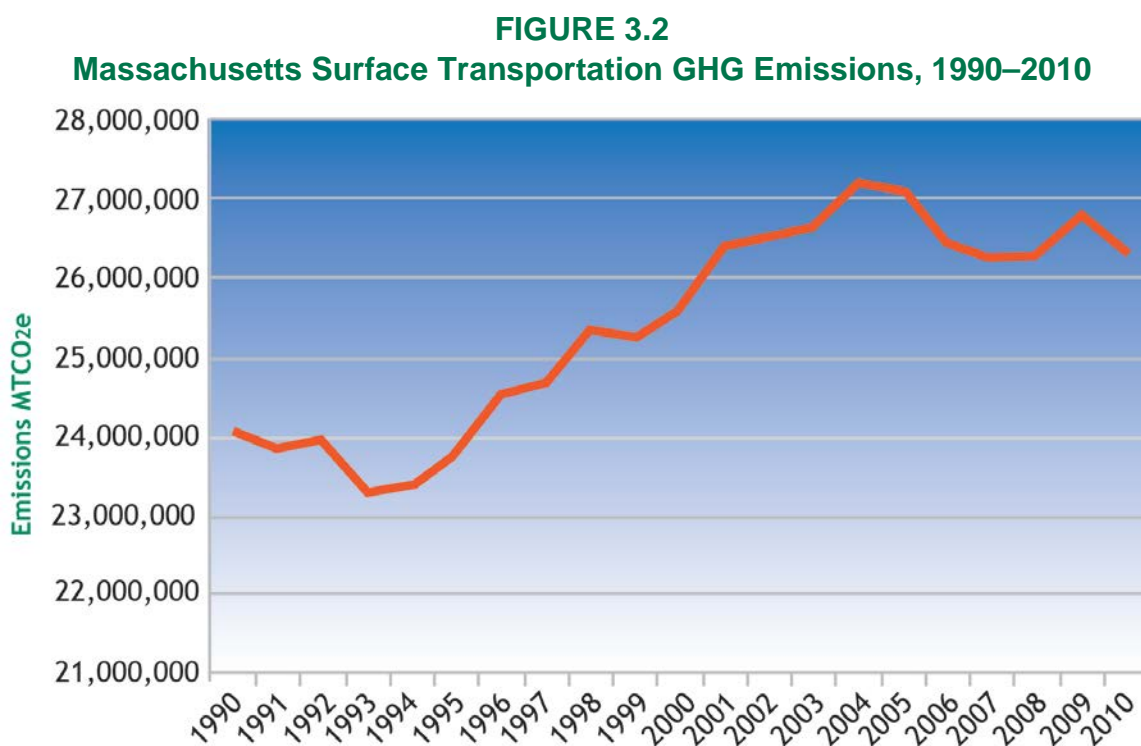
Source: *Global Warming Solutions Act 5-Year Progress Report.*

---

[14] Massachusetts Executive Office of Energy and Environmental Affairs, *Global Warming Solutions Act 5-Year Progress Report*, 2013, http://www.mass.gov/eea/docs/eea/gwsa/ma-gwsa-5yr-progress-report-1-6-14.pdf.

Staff evaluated these strategies in terms of the potential percentage of emissions reductions from the current national 2005–2050 baseline by 2030, rather than by 2020 or 2050, so some extrapolation is needed to compare the 2030 data with the Massachusetts statewide GWSA limits for this year. Figure 3.3 below shows that a 43 percent decrease from 1990 levels in all sectors would be needed to reach a theoretical 2030 goal linearly set between the 2020 and 2050 limits.

FIGURE 3.3
Massachusetts Statewide GHG Baseline and GWSA Limits, All Sectors
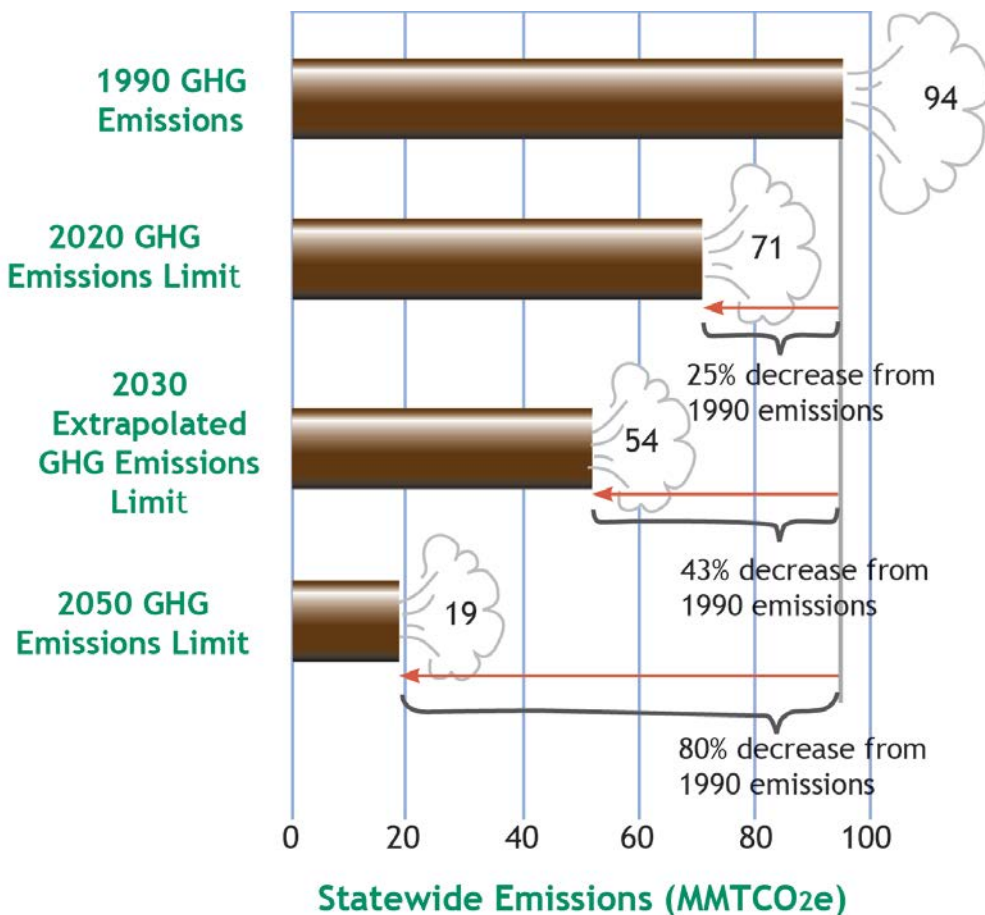
Source: Massachusetts Department of Environmental Protection, *Global Warming Solutions Act 5-Year Progress Report.*

3.2.1.2 Combining Strategies

In order to reduce GHG emissions significantly, it would be necessary to utilize multiple strategies. For example, it would take 77 strategies each with a maximum reduction potential of 0.6 percent from the baseline by 2030 to match the maximum GHG reduction potential of a cap-and-trade or carbon tax initiative (defined in chapter four), a 4.6 percent reduction in 2030. Fourteen of the 24

strategies studied in this literature review each have a maximum GHG reduction potential of 0.6 percent or less. It may be possible to achieve greater emissions reductions when combining multiple strategies, especially when a strategy with a low emissions-reduction potential is paired with one with a higher potential.

Notably, the GHG reduction potential of individual strategies cannot simply be added together to estimate the cumulative effect. As the following *Moving Cooler* example shows, the combined effects of each strategy must be multiplied, which results in a slightly smaller cumulative reduction.

> For example, imagine that implementing strategy "A" results in a 10 percent reduction [in GHG emissions] from the study baseline. Implementing strategy "B" on its own would also result in a 10 percent reduction. However if strategy "B" is implemented in addition to strategy "A", it will reduce 10 percent of the 90 percent [emissions] remaining, or 9 percent. That is, the combined effect will be 0.90 x 0.90 = 0.81, or a 19 percent combined reduction, rather than the 20 percent that would occur if the reductions were simply added.

The difference between multiplying the effects and just adding the reductions will be greater as the number of individual strategies being combined increases.[15]

Furthermore, the different strategies interact with each other, some with synergistic effects and others with opposing effects. Strategies that work together synergistically can result in GHG reductions larger than the sum of the reductions of the individual strategies. Compact development (defined in Chapter 4) in particular plays a well-studied, significant role in supporting walking, biking, car-sharing, and urban public transportation.[16] More information on this topic is available in Section 3.3.

3.2.1.3 Strategy Deployment

The level at which a strategy is deployed—expanded, aggressive, or maximum—is crucial in determining how large a GHG reduction can be achieved. The implementation of a strategy is associated with a range in GHG reductions; the high end of this range may be very promising, while the low end could be as low as no emissions reduction at all. This range reflects the variability in deployment levels. Aggressive or maximum levels of deployment of transportation demand

---

[15] Cambridge Systematics, *Moving Cooler*, p. 35.
[16] Cambridge Systematics, *Moving Cooler*, p. 35-36.

management and transportation system management strategies will be needed to reach GHG reduction limits in the Global Warming Solutions Act.

According to *Moving Cooler*, three key factors comprise the level of deployment[17]:

1. Geography: Refers to how broadly a strategy is implemented across a region, from large urban areas only to all areas including rural areas.
2. Time frame: Signifies how quickly a strategy is put into effect; since GHG emissions are cumulative, earlier cuts in emissions can provide the greatest overall impact over time and could help with meeting the first GWSA limit for 2020. Alternatively, if the implementation of a strategy is delayed, it will not have as much time to take effect by 2020 or 2030, potentially with smaller GHG reductions achieved by those dates.
3. Intensity: Describes the magnitude of implementation. For example, the difference between installing bike lanes and paths at one-mile intervals in urban areas and installing them at one-quarter-mile intervals is a difference in intensity.

Together, geography, time frame, and intensity make the difference between aggressive and maximum deployment, and in turn determine the quantity of greenhouse gas emissions that are prevented from entering the atmosphere.

3.2.2 Strategy Cost-Effectiveness

Each strategy's cost-effectiveness is quantified in terms of the direct cost to the implementing agency per $MTCO_2e$ reduced. This report discusses cost-effectiveness based on a national level of implementation. A strategy's cost or savings to the public also are provided when available, because many strategies have been found to save the public money.

For the purpose of comparison, staff divided strategies into "high," "medium," and "low" cost-effectiveness. Strategies were considered to have high cost-effectiveness if they cost less than $250 per $MTCO_2e$ reduced; low cost-effectiveness if they cost more than $500 per $MTCO_2e$ reduced; and medium cost-effectiveness if their costs fall in the middle of this range. These categories were informed by the *Incorporating Greenhouse Gas Emissions* report by the Transportation Research Board, which quantifies direct implementation costs.[18]

---

[17] Cambridge Systematics, *Moving Cooler*, p. 82.
[18] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, p. 33.

There is also uncertainty surrounding the cost-effectiveness estimates of many strategies because of limited studies on cost-effectiveness. Furthermore, the cost-effectiveness of an approach can differ considerably by location (e.g., rural versus urban), as well as context. The Transportation Research Board cautions against drawing blanket conclusions.[19] It recommends that strategies with substantial GHG reduction potential not be ruled out on the basis of cost without analyzing the local region specifically, and considering them as part of a larger set of strategies, some of which (e.g., pricing strategies) can provide revenue to support other more costly strategies.

We summarize the categories for measuring GHG reduction potential and cost-effectiveness in Table 3.2 below.

TABLE 3.2
Greenhouse Gas Reduction Potential
and Cost-Effectiveness Categories

Category	Greenhouse Gas Reduction Potential	Cost-Effectiveness
High	One percent or more reduction compared to 2030 baseline	Less than $250 per $MTCO_2e$
Medium	Between 0.5 and 1 percent compared to 2030 baseline	Between $250 and $500 $MTCO_2e$
Low	Less than 0.5 percent compared to 2030 baseline	More than $500 per $MTCO_2e$

$MTCO_2e$ = metric tons carbon dioxide equivalent.
Source: Transportation Research Board, *Incorporating Greenhouse Gas Emissions.*

3.2.3 Other Strategy Considerations

In addition to cost- and emission-effectiveness, many other considerations are important when selecting strategies for implementation. While we discuss cost-effectiveness primarily in terms of direct implementation costs, the Transportation Research Board, and Cambridge Systematics, caution against neglecting other perspectives and inaccurately representing the full social costs and benefits,[20] examples of which include
- Travel time savings
- Other welfare gains or losses (because of accessibility and increased or decreased convenience)
- Equity (incidence of costs and benefits across population groups)

---

[19] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, p. 33.
[20] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 32-33.

Resources such as *Moving Cooler* and *Transportation's Role* (Cambridge Systematics and Eastern Research Group) quantify net costs (e.g., including vehicle operating savings) when discussing cost-effectiveness, which demonstrates the prevalence of this methodology. However, they both highlight the need to consider further social costs and benefits. For example, while transit expansion and other major infrastructure improvements are not directly cost-effective, they can be worthwhile for additional purposes such as mobility, safety, and livability. They also can support a package of strategies that is collectively more cost-effective, such as when transit is paired with compact development.[21]

This report discusses additional considerations pertaining to each strategy, (where information is available), which include:

- Costs and Benefits:
    - Equity impacts
    - Social concerns
    - Unique strategy benefits
    - Unique negative effects of the strategy
- Feasibility and Timing:
    - Feasibility
    - Implementation concerns
    - Timing of benefits
- Data Needs
- MPO Role

Equity impacts can vary from strategy to strategy. Disproportionate impacts—such as those that result from pricing—on particular groups may need to be balanced or addressed. For example, lower-income groups already spend as much as four times more of their income on transportation compared to higher income groups.[22] Social concerns, highlighted in FHWA's *Reference Sourcebook for Reducing Greenhouse Gas Emissions from Transportation Sources*, consider a public perception of strategies. Unique benefits and unique negative effects include impacts on livability, safety, and the environment.

Implementation feasibility rankings for technical, institutional, and political factors are suggested in the Transportation Research Board's 2013 report, *Incorporating Greenhouse Gas Emissions into the Collaborative Decision-Making Process*. These ratings refer to the feasibility of implementation on a national scale, and may differ for Massachusetts or the Boston region. Implementation concerns may include the need for inter-agency coordination.

---

[21] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, p. 33.
[22] Cambridge Systematics, *Moving Cooler*, p. 83.

The US Department of Transportation's Report to Congress, titled *Transportation's Role in Reducing U.S. Greenhouse Gas Emissions,* was a central reference for information on timing of benefits (short, medium, or long), as well as other details. Finally, some strategies may be more directly applicable to the MPO's sphere of influence than others, and we account for this factor the descriptions of individual strategies.

3.3   DATA NEEDS

All the strategies discussed in this literature review could benefit from further research. Data on what implementation of each strategy can achieve in Massachusetts and in the Boston Region could better inform decision-making. Some strategies may be able to reduce GHG emissions in Massachusetts or the Boston Region further below a 2030 baseline than they may reduce national emissions below the national 2030 baseline.

Chapter 4—Promising Strategies for Reducing GHG Emissions Identified in Literature Review

4.1   IDENTIFIED PROMISING STRATEGIES

Strategies that were identified as being promising in terms of their ability to reduce GHG emissions include the following, starting with the most effective. In addition to GHG reduction, the strategies may address other MPO goals, as established in in its long-range transportation plan. The goals addressed by each strategy are denoted as follows:

- Safety
- System Preservation
- Capacity Management/Mobility
- Clean Air and Clean Communities
- Transportation Equity
- Economic Vitality

1. **Carbon taxes and cap-and-trade:** A carbon tax "would raise the price of fossil fuels, with more taxes collected on fuels that generate more emissions."[23] Under a cap-and-trade program, the government sets a cap on the level of emissions, and creates allowances for emissions up to the level of the cap. Entities that are sources of carbon emissions can buy or sell these allowances. **Potential to reduce GHG emissions nationally by 2.8 to 4.6 percent from the 2030 baseline.**

2. **Driver education/eco-driving:** Eco-driving refers to smarter and more energy-efficient driving, such as accelerating and braking smoothly. Eco-driving practices can be encouraged through educational campaigns and via "dynamic eco-driving" where technology provides real-time efficiency feedback. **Potential to reduce GHG emissions nationally by 0.8 to 3.7 percent from the 2030 baseline.**

3. **Pay-as-you-drive insurance:** Under a pay-as-you-drive insurance system, drivers are charged for vehicle insurance based on their vehicle-miles-traveled. **Potential to reduce GHG emissions nationally by 1.1 to 3.5 percent from the 2030 baseline.**

---

[23] http://www.nytimes.com/2015/06/07/opinion/the-case-for-a-carbon-tax.html.

4. **Compact Development:** Compact development can reduce the need for travel because destinations and activities are in close proximity to one another. **Potential to reduce GHG emissions nationally by 0.2 to 3.5 percent from the 2030 baseline.**

5. **Required Employer-Offered Compressed Work Weeks:** Compressed work weeks save greenhouse gas emissions by reducing the number of days that employees need to commute to their workplaces, thus the total amount of vehicle-miles-traveled each week. This assumes that employees would make other non-work related trips during that time, but only using a fraction of the VMT for a typical workday. Compressed-work-week policies could make the choice of a compressed work week either voluntary or mandatory for employees. **Potential to reduce GHG emissions nationally by 0.1 to 2.4 percent from the 2030 baseline, depending on the policy approach taken.**

6. **Vehicle-Miles-Traveled Fees**: These are distance-based fees levied on a driver for using a roadway system. As opposed to tolls, which are facility specific and not necessarily levied strictly on a per-mile basis, these fees are based on the distance driven on a defined network of roadways.[24] **Potential to reduce GHG emissions nationally by 0.8 to 2.3 percent from the 2030 baseline.**

7. **Reduced Speed Limits:** Because vehicles rapidly lose fuel economy as they increase speeds above 50 mph, setting this at the maximum speed prevents wasted fuel by helping drivers achieve maximum efficiency.[25] **Potential to reduce GHG emissions nationally by 1.2 to 2.0 percent from the 2030 baseline.**

8. **Congestion Pricing:** This concept involves charging for travel during peak periods on in certain locations. Some drivers may choose to bypass congestion by using priced lanes, particularly when they are in a hurry and value the time savings. In other cases, people may choose not to travel in certain locations or at certain times to avoid congestion-pricing. **Potential to reduce GHG emissions nationally by 0.5 to 1.6 percent from the 2030 baseline.**

---

[24] U.S. Department of Transportation, Federal Highway Administration, Road Pricing Defined, http://www.fhwa.dot.gov/ipd/revenue/road_pricing/defined/vmt.aspx.

[25] U.S. Department of Energy, www.fueleconomy.gov, Driving More Efficiently, http://www.fueleconomy.gov/feg/driveHabits.jsp (accessed March 17, 2015).

9. **Alternative Road Construction Materials.** State and local highway departments and other transportation agencies can utilize less energy-intensive materials in highway construction projects to cut their greenhouse gas emissions.[26] **Potential to reduce GHG emissions nationally by 0.7 to 0.8 percent from the 2030 baseline.**
   ●

10. **Expansion of Fixed-Guideway Transit:** In the Boston region, this would entail extending the MBTA's existing rapid transit subway lines or adding new rail or bus rapid transit lines. **Potential to reduce GHG emissions nationally by 0.17 to 0.65 percent from the 2030 baseline.**
    ● ● ● ●

11. **Teleworking:** Teleworking, or telecommuting, occurs when employees conduct their workday(s) at home or otherwise outside their employer's office, using telecommunications and computer technology to bridge the distance. **Potential to reduce GHG emissions nationally by 0.5 to 0.6 percent from the 2030 baseline.**
    ● ●

12. **Increased Transit Service:** Improvements, such as reduced transit headways, could increase ridership and could decrease the use of single-occupant vehicles by shifting travel from the automobile to transit modes. **Potential to reduce GHG emissions nationally by 0.2 to 0.6 percent from the 2030 baseline.**
    ● ● ● ●

13. **Workplace Transportation Demand Management (TDM) (General):** TDM refers to strategies that increase system efficiency by encouraging a shift from single-occupant vehicle (SOV) trips to non-SOV modes (such as carpools or public transit), or shifting auto trips out of peak periods.[27] Workplace TDM can take the form of requirements for employers to reduce SOV trips or conduct informational and encouragement TDM strategy programs. **Potential to reduce GHG emissions nationally by 0.1 to 0.6 percent from the 2030 baseline.**
    ● ● ●

---

[26] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, p. 4-6.

[27]

http://www.seattle.gov/transportation/docs/ump/07%20SEATTLE%20Best%20Practices%20in%20Transportation%20Demand%20Management.pdf.

14. **Pedestrian improvements:** These include adding or improving sidewalks, crosswalks, crossing signals, shared-use paths, and other facilities, which would support non-motorized travel. **Potential to reduce GHG emissions nationally by 0.10 to 0.31 percent from the 2030 baseline.**

● ● ● ● ●

15. **Transit Fare Reductions:** Reduced fares could potentially increase ridership and could decrease the use of single-occupant vehicles. **Potential to reduce GHG emissions nationally by 0.09 to 0.28 percent from the 2030 baseline.**

● ● ●

16. **Individualized Marketing:** This strategy targets people who are interested in or open to alternative modes of transportation, then provides them with customized contacts and transportation mode information. **Potential to reduce GHG emissions nationally by 0.14 to 0.28 percent from the 2030 baseline.**

● ● ●

17. **Truck-Idling Reduction:** In addition to idling in traffic, drivers may idle their trucks while they are parked to keep the truck warm, allow it to build air pressure for the release of its brakes, or to power auxiliary systems. Reducing idling in turn can reduce fuel use and greenhouse gas emissions. **Potential to reduce GHG emissions nationally by 0.09 to 0.28 percent from the 2030 baseline.**

● ●

18. **Bicycle Improvements:** These include bike lanes and off-road paths, which would support non-motorized travel, eliminating VMT. **Potential to reduce GHG emissions nationally by 0.09 to 0.28 percent from the 2030 baseline.**

● ● ● ● ●

19. **Information to Support Vehicle Purchases:** This includes campaigns that assign a special designation to vehicles that perform well in order to reduce greenhouse gas emissions and air pollution. **Potential to reduce GHG emissions nationally by 0.09 to 0.23 percent from the 2030 baseline.**

● ●

20. **Rail Freight Infrastructure:** Moving goods by rail can be more energy-efficient than moving goods by truck. Therefore, shifting or diverting freight from trucks to rail can reduce greenhouse gas emissions. Infrastructure improvements, financial incentives or disincentives, and other policy

and regulatory actions can encourage shippers to move goods from trucks to rail. **Potential to reduce GHG emissions nationally by 0.01 to 0.22 percent from the 2030 baseline.**

21. **Parking Management:** Changes to parking prices, supply, and other management techniques that can discourage driving are called parking management. Parking management can be used to encourage people to walk, bike, take transit, or use other non-SOV modes to reach their destinations, and to reduce time to search for parking. **Potential to reduce GHG emissions nationally by 0.20 percent from the 2030 baseline.**

22. **Car Sharing:** This describes a system where members pay to rent vehicles as needed on a per-trip hourly basis, either from companies or via peer-to-peer sharing. People who use car-sharing services can access cars without car ownership. Therefore, they may choose to forego owning their own vehicles. **Potential to reduce GHG emissions nationally by 0.05 to 0.20 percent from the 2030 baseline.**

23. **Ride Sharing:** Ride matching, carpooling, and vanpooling jointly are called ride sharing, and can reduce VMT by increasing vehicle occupancies for work trips. Ride sharing may be supported by internet technologies, mobile phones, or programs that reimburse employees for the costs of taxi rides or rental cars in the event of an emergency. **Potential to reduce GHG emissions nationally by 0.0 to 0.2 percent from the 2030 baseline.**

Detailed descriptions and evaluations of these individual strategies are available in Appendix A.

One other potential strategy for reducing greenhouse gas emissions is the use of buses and other non-fixed guideway transit services. Unfortunately, this strategy was not evaluated in Incorporating Greenhouse Gas Emissions or Moving Cooler, and more research is needed to determine its GHG reduction potential. However, the Federal Transit Administration data on average CO2 emissions per passenger mile by mode show that the emission rate from private automobiles is higher than that from bus transit (although the bus transit rate is higher than the various rail rates). Bus transit emission rates are also projected to decrease by 50 percent by 2050 because of technological improvements.[28]

---

[28] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, Volume 2, 5-35, 5-38.

4.2   GHG REDUCTION POTENTIAL AND COST-EFFECTIVENESS OF PROMISING STRATEGIES

4.2.1   Promising Strategies and the MPO Framework

The MPO's 2012 update to the *Carbon Dioxide, Climate Change, and the Boston Region MPO* report, cited possible MPO actions and partnership opportunities that fall into three categories:

- Creating a more efficient transportation system that has lower GHG emissions
- Promoting fuel efficiency and cleaner vehicles
- Coordinating transportation with land use decisions

Table 4.1 below presents our literature review strategies in context of these categories. The table also documents the strategies' relationship to the GreenDOT goals outlined in Chapter 1. The strategies also fall into general strategy types, which were identified in Section 3.1.

TABLE 4.1
Promising Strategies by Type, Relationship to GreenDOT, and Potential MPO Role in Implementation

Category	Strategy	Strategy Type	Relationship to GreenDOT	Potential MPO Role
Creating a More Efficient Transportation System That Has Lower GHG Emissions	Pedestrian Improvements	Transportation System Planning, Funding, and Design	Promote Healthy Transportation Modes	Fund or Study
	Bicycling Improvements	Transportation System Planning, Funding, and Design	Promote Healthy Transportation Modes	Fund or Study
	Expansion of Urban Fixed-Guideway Transit	Transportation System Planning, Funding, and Design	Promote Healthy Transportation Modes	Fund or Study
	Rail Freight Infrastructure	Transportation System Planning, Funding, and Design	Reduce Transportation-Related GHG	Fund or Study
	Alternative Construction Materials	Construction and Maintenance Practices	Reduce Transportation-Related GHG	Advocate
	Increased Transit Service	Transportation System Management and Operations	Promote Healthy Transportation Modes	Fund or Study

Category	Strategy	Strategy Type	Relationship to GreenDOT	Potential MPO Role
	Transit Fare Reductions	Transportation System Management and Operations	Promote Healthy Transportation Modes	Study
	Carbon Tax or Cap-and-Trade	Taxation and Pricing	Reduce Transportation-Related GHG	Study or Advocate
	Pay-As-You-Drive Insurance	Taxation and Pricing	Reduce Transportation-Related GHG	Study or Advocate
	Vehicle-Miles-Traveled Fees	Taxation and Pricing	Reduce Transportation-related GHG	Study or Advocate
	Congestion Pricing	Taxation and Pricing	Reduce Transportation-Related GHG	Study or Advocate
	Workplace Transportation Demand Management	Travel Demand Management	Reduce Transportation-related GHG	Fund or Study
	Teleworking	Travel Demand Management	Reduce Transportation-Related GHG	Fund or Study
	Compressed Work Weeks	Travel Demand Management	Reduce Transportation-Related GHG	Study
	Individualized Marketing of Transportation Services	Travel Demand Management	Reduce Transportation-Related GHG	Fund
	Ride sharing	Travel Demand Management	Reduce Transportation-Related GHG	Fund or Study
	Car sharing	Travel Demand Management	Reduce Transportation-Related GHG	Fund or Study
Promote Fuel Efficiency and Cleaner Vehicles	Truck-Idling Reduction	Transportation System Management and Operations	Reduce Transportation-Related GHG	Fund or Study
	Reduced Speed Limits	Transportation System Management and Operations	Reduce Transportation-Related GHG	Study or Advocate
	Driver Education and Eco-Driving	Other Public Education	Reduce Transportation-Related GHG	Publicize

Category	Strategy	Strategy Type	Relationship to GreenDOT	Potential MPO Role
	Information on Vehicle Purchases	Other Public Education	Reduce Transportation-Related GHG	Publicize
Coordinate Transportation with Land Use Decisions	Compact Development	Land Use Codes, Regulations, and Policies	Support Smart Growth through transportation investment	Study or Advocate
	Parking Management	Land Use Codes, Regulations, and Policies	Reduce Transportation-Related GHG	Fund or Study

Source: Central Transportation Planning Staff.

4.2.2 Findings on Promising Strategies

The 24 strategies in Table 4.2 below are listed from most to least promising in terms of their maximum ability to affect national transportation emissions. There is an extra strategy in this table (also described in Appendix A) because compressed work week is separated into two distinct programs—required employer-offered compressed work week and compressed work week: mandatory public and voluntary private. Data for these strategies was compiled by the Transportation Research Board in the *Incorporating Greenhouse Gas Emissions into the Collaborative Decision-Making Process* report.[29] The percentages represent the possible reductions in national annual transportation emissions compared to 2005 levels, and the costs are expressed in dollars per metric ton of CO_2e reduced. The Transportation Research Board's 2013 report was used as the primary source of quantitative information since it is the most recent comprehensive compilation of data on this topic. Significantly, it also has converted GHG reduction information from other sources into the same units to facilitate comparison—information is often expressed in different units across different sources.

The table also indicates where there is potential for the Boston Region MPO to directly fund, fund with partnerships, or study/model each strategy. The MPO can directly fund a strategy if it involves expanding a current program, or if the strategy falls under the jurisdiction of a MPO more than that of a Regional Planning Agency (RPA). While this distinction is blurry for regional organizations where the MPO and the RPA are represented by the same regional organization, the difference is more significant for the Boston Region MPO, which is separate from the region's RPA, the Metropolitan Area Planning Council (MAPC). Strategies that may be more appropriate for RPAs and for which the MPO likely

---

[29] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, pp. 22-26.

would need to work together with MAPC toward implementation are categorized as strategies that the MPO can fund with partnerships. Potential partners for strategies that could be funded with partnerships also include state and local organizations that already conduct outreach for transportation demand management.

Finally, there are other strategies that cannot be funded by the MPO, but could be studied or modeled. While studies alone do not reduce greenhouse gas emissions, they may be useful to support a strategy's implementation.

Also included in this table is information about timing of benefits (short, medium, or long); and the table poses the following questions for each strategy:

- *Technological Feasibility*: Is the technology well developed and proven in practice? What is the likelihood that the technology could be implemented in the near future at the deployment levels assumed in the analysis? Technological barriers can be low-tech as well as high-tech (for example, there may be right-of-way constraints to infrastructure expansion in urban areas).
- *Institutional Feasibility*: Do government agencies have the authority and resources to implement the strategy? What is the administrative ease of running the program; and what are the levels of coordination required among various stakeholders?
- *Political Feasibility*: Is the strategy generally popular or unpopular with any interested stakeholders, elected officials, and the general public? What is the political influence of those supporting versus those opposed to the strategy?

Feasibility is assessed without respect to cost, which was evaluated as part of the cost-effectiveness measure.

TABLE 4.2
Evaluation of Promising Transportation GHG Reduction Strategies [a] (Based on National Data)

Strategy	GHG Reduction [b] (Rating)	GHG Reduction [b] (Pct. Change from 2030 Baseline)	Relative Max. Reduction as Percent of GHG Reduction of Combined Strategies [c]	Direct Cost-Effect. (Rating)	Direct Cost-Effect. [b] (Dollars per unit)	Technological Feasibility [b] (Rating)	Institutional Feasibility [b] (Rating)	Political Feasibility [b] (Rating)	MPO Role
Carbon tax or cap-and-trade	High	2.8–4.6%	15.0%	N/A	N/A	Medium	Medium	Low-to-Medium	Study or Advocate
Driver education/eco-driving	High	0.8–3.7%	12.1%	High[d]	N/A	Low	Low	High	Publicize[†]
Pay-as-you-drive insurance	High	1.1–3.5%	11.4%	High	$30–$90	Low-to-Medium	Low-to-Medium	Medium	Study or Advocate
Compact development	High	0.2–3.5%	11.4%	High	$10	Medium	Low	Low	Study or Advocate
Compressed work week requirement	High	2.4%	11.1%	High	$1	High	Low	Low-to-high	Study
VMT fee	High	0.8–2.3%	7.5%	High	$60–150	Low	High	Low	Study or Advocate
Reduced speed limits	High	1.2–2.0%	6.5%	High	$10	High	Medium-to-High	Low	Study or Advocate
Congestion pricing	High	0.5–1.6%	5.2%	Medium	$340	Low	High	Low	Study or Advocate
Alternative road construction materials	Medium	0.7–0.8%	2.6%	Low-to-High	$0–$770	Medium-to-High	Medium	Medium-to-High	Advocate
Expansion of urban fixed-guideway transit	Medium	0.17–0.65%	2.1%	Low	$1,800–2,000	Medium	High	Medium	Fund or Study
Teleworking	Medium	0.5–0.6%	2.0%	Low	$1,200–2,300	Medium	Low	Medium-to-High	Fund or Study
Increased transit service	Medium	0.2–0.6%	2.0%	Low	$3,000–$3,300	High	High	High	Fund or Study

Strategy	GHG Reduction [b] (Rating)	GHG Reduction [b] (Pct. Change from 2030 Baseline)	Relative Max. Reduction as Percent of GHG Reduction of Combined Strategies [c]	Direct Cost-Effect. (Rating)	Direct Cost-Effect. [b] (Dollars per unit)	Technological Feasibility [b] (Rating)	Institutional Feasibility [b] (Rating)	Political Feasibility [b] (Rating)	MPO Role
Workplace TDM (general)	Medium	0.1–0.6%	2.0%	High	$30–$180	High	Low-to-High	High	Fund or Study
Pedestrian improvements	Low	0.10–0.31%	1.0%	High	$190	High	Low-to-Medium	Medium	Fund or Study
Compressed workweek for government and voluntary private	Low	0.1–0.3%	1.0%	NA	N/A	High	Low	Low-to-High	Study
Transit fare reduction	Low	0.09–0.3%	1.0%	Low	$1,300	High	High	High	Study
Individualized marketing of transportation services	Low	0.14–0.28%	0.9%	High	$90	Medium	Medium	High	Fund [f]
Truck-idling reduction	Low	0.09–0.28%	0.9%	High	$20	High	Medium	Medium	Fund or Study
Bicycle improvements	Low	0.09–0.28%	0.9%	High	$80–210	Medium	Low	Medium	Fund or Study
Information on vehicle purchases	Low	0.09–0.23%	0.8%	Low-to-Medium [e]	N/A	High	High	High	Publicize [f]
Rail freight infrastructure	Low	0.01–0.22%	0.7%	High	$80–200	Medium	Medium	Low-to-High	Fund or Study
Parking management	Low	0.2%	0.7%	N/A	N/A	High	Low	Low	Fund or Study
Car sharing	Low	0.05–0.20%	0.7%	High	<$10	High	Medium	High	Fund or Study [f]
Ride sharing	Low	0.0–0.2%	0.7%	High	$80	High	Low-to-Medium	High	Fund or Study [f]

[a] Strategies with the potential to reduce national transportation GHG emissions by at least 0.2 percent.

[b] Source: Transportation Research Board, *Incorporating GHG Emissions* unless otherwise noted

[c] Percent of reduction needed to meet GWSA limits if the GWSA limits are applied nationally and the 2030 goal is set linearly between the 2020 and 2050 limits.

[d] Source: U.S. Department of Transportation, Federal Highway Administration, *Reference Sourcebook for Reducing Greenhouse Gas Emissions from Transportation Sources*, 2012, by Rand Corporation and RSG, Inc., http://www.fhwa.dot.gov/environment/climate_change/mitigation/publications_and_tools/reference_sourcebook/referencesourcebook.pdf p. 204.

[e] Source: Cambridge Systematics and Eastern Research Group, *Transportation's Role*, p. 5-96, 5-97.

[f] Publicize potentially using CMAQ funds.

Figure 4.1 below is a bar chart that displays each strategy's relative maximum potential for GHG emissions reductions from the national 2030 baseline. There are large differences between the strategies with the greatest potential and those with relatively small potential. Eight strategies with "high" GHG reduction potential hold roughly four-fifths of the potential for GHG reductions, while the remaining 16 strategies with lower GHG reduction potential represent one-fifth of the total potential. Of the top eight strategies, one can be funded by the MPO— driver education/eco-driving, and the MPO can only publicize information about the program.

Other strategies should not be discounted in importance automatically based on their smaller relative potential for reductions. Many strategies can affect the success of others, or are important for balancing equity and other needs of the transportation system as a whole. For instance, if a VMT fee increases the cost of driving in order to discourage single occupancy vehicles, then there needs to be safe and comfortable transportation choices—such as public transit, walking, and biking—available to former drivers.

FIGURE 4.1
Transportation GHG Reduction Strategies: Maximum Potential for National Emissions Reductions as a Percentage Reduction from National 2030 Baseline

1. Carbon tax or cap-and-trade
2. Driver education/eco-driving
3. Pay-as-you-drive insurance
4. Compact development
5. Compressed work week: employer offered
6. VMT fee
7. Reduced speed limits
8. Congestion pricing
9. Alternative road construction material
10. Expansion of urban fixed-guideway transit
11. Teleworking
12. Increased transit service
13. Workplace TDM (general)
14. Pedestrian improvements
15. Compressed work week: public & private
16. Transit fare reduction
17. Individualized marketing
18. Truck idling reduction
19. Bicycle improvements
20. Information on vehicle purchase
21. Rail freight infrastructure
22. Parking management
23. Carsharing
24. Ridesharing

Source: Incorporating Greenhouse Gas Emissions.

Figure 4.2, below, displays the average direct cost-effectiveness of strategies for which cost information is available. (No cost data is available for carbon tax/cap-and-trade, driver education/eco-driving, compressed government workweek: mandatory public and voluntary private, information on vehicle purchase, or parking management.) Thirteen of the strategies have high cost-effectiveness, from compressed workweek requirements to pedestrian improvements. Four of the strategies typically have low cost-effectiveness: improved transit headways and level of service, expansion of urban fixed-guideway transit, teleworking, and transit fare reduction.

Note that strategies that are not cost-effective may still be valuable to implement. Some of the least-cost effective strategies, namely the transit-focused strategies, and teleworking have the ability to achieve large reductions in total; without these strategies, the largest emission reductions cannot be achieved, In addition, both the transit strategies and teleworking have many other benefits that support cost expenditures, in addition to GHG reduction. These strategies have important mobility and accessibility benefits. A strategy involving capital expenditures on infrastructure may not be cost-effective per ton of GHG reduced, but could be cost-effective compared to infrastructure providing similar transportation services.

FIGURE 4.2
Transportation GHG Reduction Strategies: National Average Direct Cost-Effectiveness [a]

1. Compressed work week: employer offered
2. Compact development
3. Reduced speed limits
4. Carsharing
5. Truck idling reduction
6. Pay-as-you-drive insurance
7. Ridesharing
8. Individualized marketing
9. Workplace TDM (general)
10. VMT fee
11. Rail freight infrastructure
12. Bicycle improvements
13. Pedestrian improvements
14. Congestion pricing
15. Alternative road construction materials
16. Transit fare reduction
17. Teleworking
18. Expansion of urban fixed-guideway transit
19. Increased transit service

[a] No cost-effectiveness data is available for carbon tax/cap-and-trade, driver education/eco-driving, compressed government workweek with some private, information on vehicle purchase, or parking management; these strategies were not included in the figure.
Source: *Incorporating GHG Emissions.*

4.2.3 The MPO's Role in Implementing Promising Strategies

If the maximum potential of all the strategies to reduce GHGs is added and represented by 100 percent total maximum potential, MPO-fundable strategies contribute 27 percent to this total with roughly half of the potential composed of strategies that the MPO can only help publicize (see Figure 4.3). Driver education/eco-driving is responsible for 44 percent of the GHG reduction potential of the group of MPO-fundable strategies, but this can only be publicized by the MPO; 13 other strategies make up the remaining 56 percent, and include:

1. Driver education/eco-driving (publicize only)
2. Expansion of urban fixed-guideway transit
3. Teleworking
4. Increased transit service
5. Workplace TDM (general)
6. Pedestrian improvements
7. Individualized marketing
8. Bicycle improvements
9. Truck-idling reduction
10. Information on vehicle purchase (publicize only)
11. Rail freight infrastructure
12. Car sharing
13. Ride sharing
14. Parking management

FIGURE 4.3
MPO-Fundable GHG Reductions as a Percent of Maximum Potential [a]
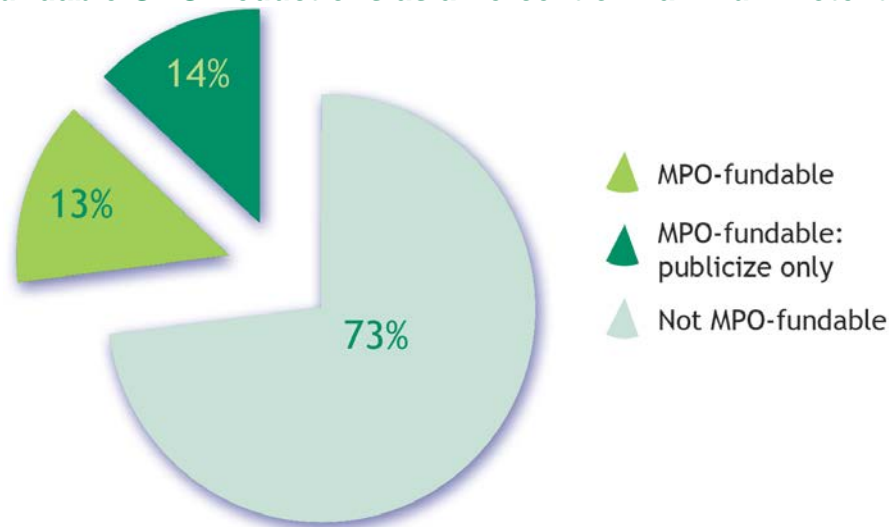
[a] The MPO can only fund publicity for driver education/eco-driver and information on vehicle purchase; it does not have the ability to implement these strategies directly.
Source: Central Transportation Planning Staff.

Note that while the MPO does have the ability to work towards many strategies and affect the region's transportation-related greenhouse gas emissions, the MPO alone likely could not achieve full implementation of some the strategies that it can support with funding. For example, the MPO could provide funding to build protected bicycle lanes, and every protected bicycle lane built helps reduce the region's greenhouse gas emissions. However, the MPO's budget does not individually support aggressive implementation of the bicycle improvement strategy; on its own, the MPO may be unable to fund bike lanes and paths at one-quarter-mile intervals, or even one-mile intervals, in high-density areas throughout the entire region.

Of the strategies that the MPO can fund either directly or with partnerships, the maximum GHG reduction potential of each of the strategies varies greatly. As shown in Figure 4.4, driver education/eco-driving (for which the MPO can publicize only) potentially could reduce greenhouse gas emissions by nearly the same amount potentially achieved by all 13 of the other MPO-fundable strategies combined. Other smaller differences are distinguishable between strategies. For example, expansion of urban fixed-guideway transit has more than 300 percent more potential to reduce GHGs than the ride-sharing strategy. Similarities between different strategies also are of interest: teleworking and general workplace transportation demand management can achieve nearly the same GHG reduction as expansion of urban fixed-guideway transit and increased transit service.

FIGURE 4.4
MPO-Fundable GHG Reduction Strategies: Maximum Potential for Emissions Reductions as Percent Reduction from the National 2030 Baseline
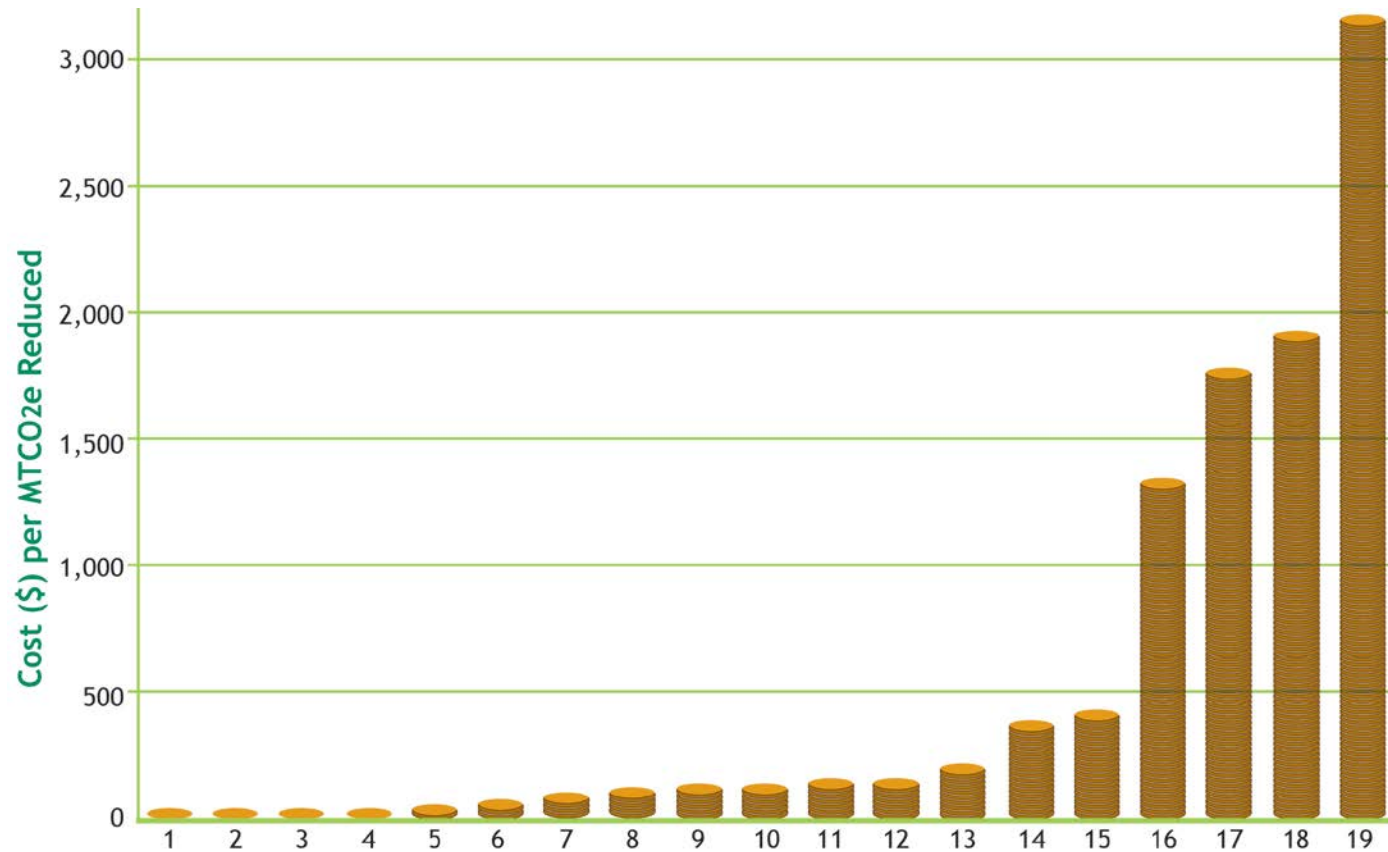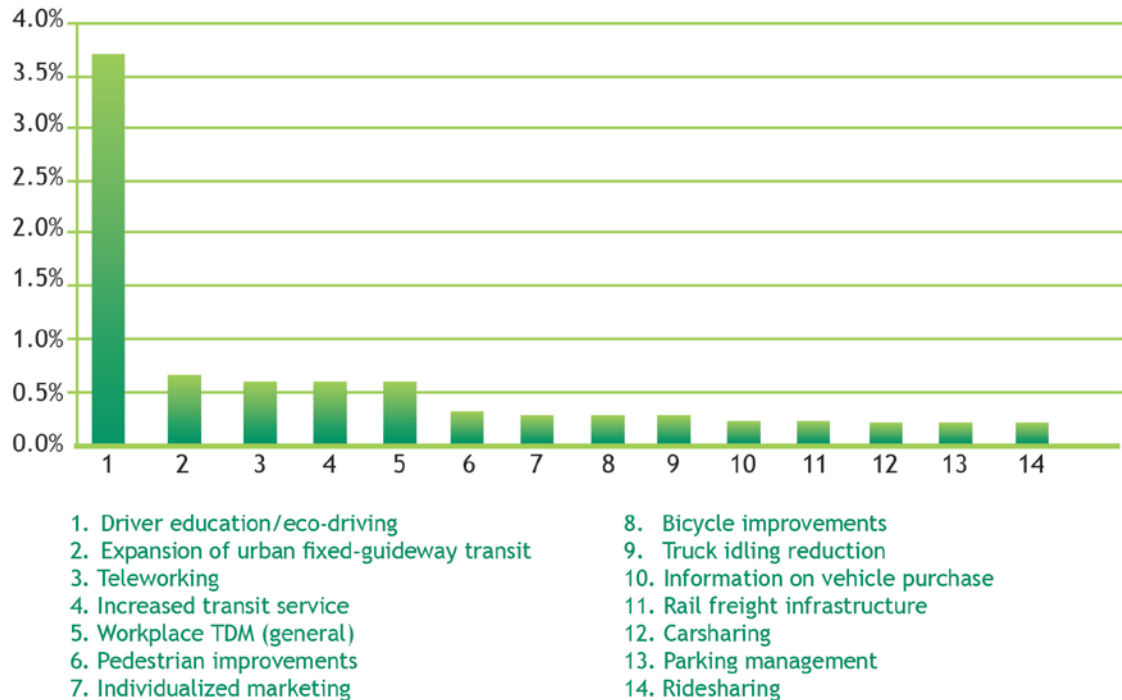

1. Driver education/eco-driving
2. Expansion of urban fixed-guideway transit
3. Teleworking
4. Increased transit service
5. Workplace TDM (general)
6. Pedestrian improvements
7. Individualized marketing
8. Bicycle improvements
9. Truck idling reduction
10. Information on vehicle purchase
11. Rail freight infrastructure
12. Carsharing
13. Parking management
14. Ridesharing

Source: *Incorporating Greenhouse Gas Emissions and Central Transportation Planning Staff.*

Figure 4.5, below, shows that many strategies that the MPO can fund are highly cost-effective. Car sharing, truck-idling reduction, ride sharing, individualized marketing, workplace TDM (general), rail freight infrastructure, bicycle improvements, and pedestrian improvements all have highly cost-effective direct implementation expenses of less than $250 per $MTCO_2e$. Increased transit service, expansion of urban fixed-guideway transit, and teleworking are much less cost-effective in terms of direct costs. However, these strategies should not be ruled out based on cost alone because they hold potential for large greenhouse gas reductions when they interact synergistically with multiple other cost-effective strategies, and can benefit the transportation system in many ways other than greenhouse gas emissions. Note that cost-effectiveness information is not available for driver education/eco-driving, information on vehicle purchase, and parking management.

FIGURE 4.5
MPO-Fundable GHG Reduction Strategies: National Average Direct Cost-Effectiveness [a]

1. Carsharing
2. Truck idling reduction
3. Ridesharing
4. Individualized marketing
5. Workplace TDM (general)
6. Rail freight infrastructure
7. Bicycle improvements
8. Pedestrian improvements
9. Teleworking
10. Expansion of urban fixed-guideway transit
11. Increased transit service
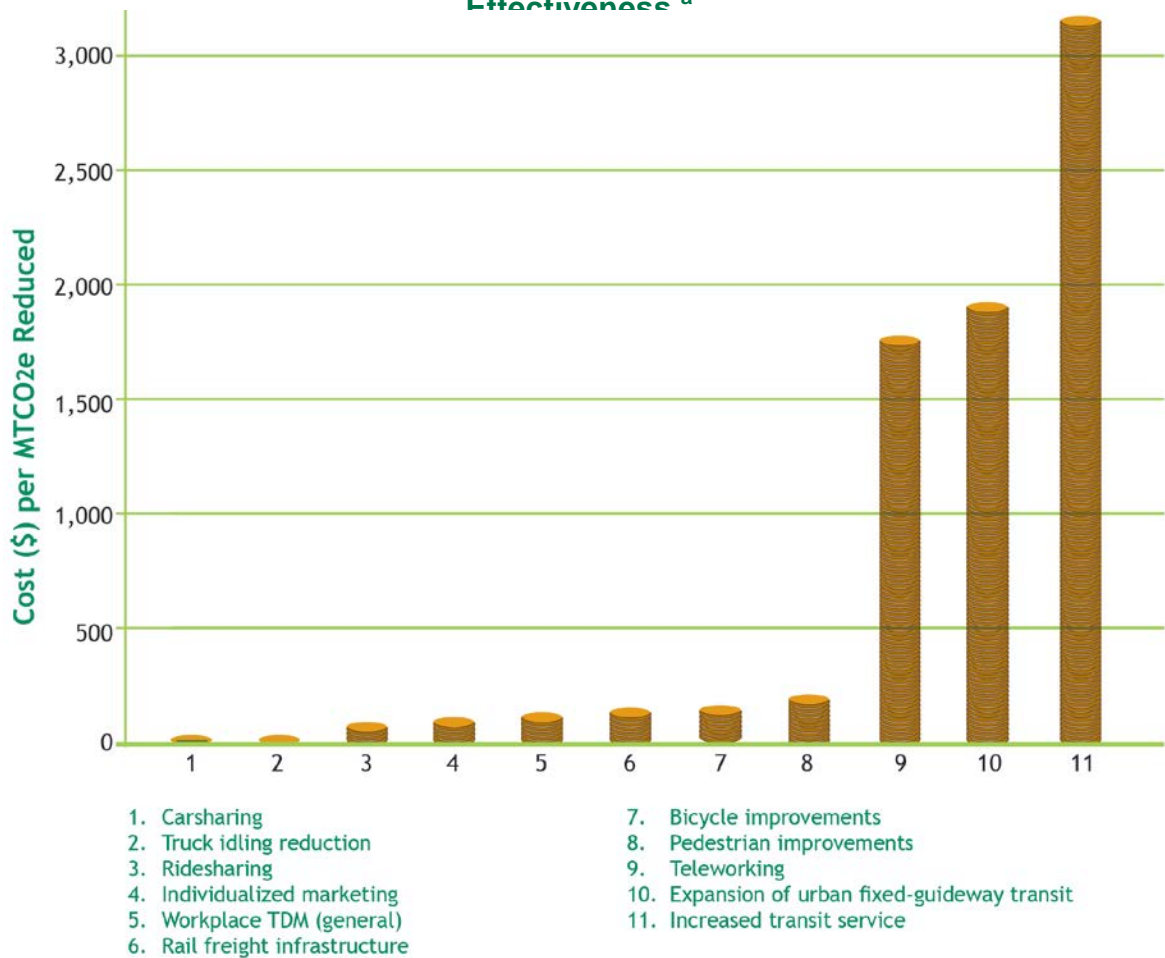
[a] No cost-effectiveness data is available for the driver education/eco-driving, information on vehicle purchase, and parking management.
Source: *Incorporating Greenhouse Gas Emissions and Central Transportation Planning Staff.*

4.3   COMBINING GHG REDUCTION STRATEGIES

Most individual strategies have modest GHG reductions of less than one percent of total transportation emissions, but combining the effects of multiple strategies could help to achieve larger reductions when paired with other strategies. The GHG reduction potential of individual strategies, however, cannot simply be added together to get the cumulative effect. Before any synergistic effects are taken into account, the effects of each strategy must be multiplied by the effects of the others, resulting in a slightly smaller effect than if the individual reductions were added.

As discussed in Section 3.1, the difference between multiplying the effects and just adding the reductions will be greater when a larger number of strategies are combined.[30] Furthermore, the different strategies interact with each other, some with synergistic effects and others with opposing effects. Strategies that work together synergistically can result in GHG reductions larger than the sum of the reductions of the individual strategies. It is important to keep these factors in mind when considering combinations, or "bundles" of GHG reduction strategies.

In order to see how effective a GHG reduction strategy bundle is at helping meet statewide *Global Warming Solutions Act* limits, we can imagine how far below the national 1990 baseline the bundle can reduce emissions. The Transportation Research Board suggests that combined strategies could achieve five-to-20 percent cuts to transportation emissions in 2030.[31] *Moving Cooler* provides somewhat higher estimates of 12-to-30 percent for 2030 reductions and 18-to-35 percent for 2050 reductions through aggressively implemented strategies (lower estimates) or maximally implemented strategies with economy-wide pricing via a price on carbon, a VMT fee, and pay-as-you-drive insurance (higher estimates).[32] The higher *Moving Cooler* estimates most competitively tackle the GWSA 2020 and 2050 limits.

Moving Cooler examined six strategy bundles, which offer insight into how different strategies might be grouped, and how different strategies influence each other positively or negatively. Strategies are evaluated in terms of multiple variables. In addition to GHG reduction and cost-effectiveness, two sample considerations are equity and net cost savings were considered when bundling strategies. Equity is of particular interest when selecting and balancing strategies; pricing strategies may be made more equitable for low-income groups if the revenues from pricing are used to fund transit and other transportation modes.[33] Another consideration when balancing strategies is overall net cost savings; most strategy bundles realize a net savings when vehicle operation cost savings are weighed against the direct implementation costs.[34]

Each of the six bundles emphasizes a different focus: timing of benefits, magnitude of total GHG reduction, land use and transportation system infrastructure, efficiency, facility pricing, and direct implementation costs. While bundles focused on infrastructure cost more than bundles focused on services, pricing, or regulations, all of the bundles except the facility pricing bundle resulted in vehicle operation cost savings greater than direct implementation costs.

---

[30] Cambridge Systematics, *Moving Cooler*, p. 35.

[31] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, p. 33.

[32] Cambridge Systematics, *Moving Cooler*, p. 82.

[33] Cambridge Systematics, *Moving Cooler*, p. 35.

[34] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, p. 31.

The bundles demonstrate that strategies can be combined effectively to "provide high-quality transportation services while achieving meaningful GHG reductions." Land use changes and improved transit and transportation options will lead to notable reductions beyond 2030, recommending them to policymakers who are focused on the 2050 GWSA limit.[35]

The next two sections examine two of the strategy bundles analyzed in *Moving Cooler*, the Low-Cost bundle and the Long-Term/Maximum Results bundle.

4.3.1 The Low-Cost Strategy Bundle

The Low-Cost bundle is of particular interest to policymakers who are constrained by cost-effectiveness. Of the 24 strategies that were highlighted in this literature review, the Low-Cost Bundle roughly includes the following GHG reduction strategies, sorted from largest to smallest potential GHG reduction:

- Driver education/eco-driving
- Compact development
- Reduced speed limits
- Congestion pricing
- Workplace TDM (general)
- Pedestrian improvements
- Transit fare reduction
- Truck idling reduction
- Bicycle improvements
- Parking management
- Car sharing
- Ride sharing[36]

In addition to these strategies, the Low-Cost bundle also names intercity tolls, and a number of strategies in two other categories—systems operations and management strategies and multimodal freight strategies. The systems operations and management strategies are:

- Freeway management (ramp metering, variable message signs, active traffic management, and integrated corridor management)
- Incident management, traveler information, and vehicle infrastructure integration

---

[35] Cambridge Systematics, *Moving Cooler*, pp. 80-83.

[36] Note: While this strategy was not studied in Moving Cooler, it was analyzed by Cambridge Systematics the following year and seems to fall under the Low Cost bundle's "employer-based commute measures."

The multimodal freight strategies listed are:
- Shipping container permits
- Longer combination vehicle permits
- Weigh-in-motion screening
- Weigh station bypass
- Urban consolidation centers[37]

Without economy-wide pricing, at maximum deployment, this bundle achieves 91 percent of the reductions possible with the Long-Term/Maximum Results bundle, the bundle with the greatest GHG reduction potential. If economy-wide pricing measures are put in place, the GHG reductions achieved by both bundles improve dramatically, and the Low-Cost bundle performs within one-tenth the cumulative 2010 to 2050 effect of the Long-Term/Maximum Results bundle.[38]

However, Cambridge Systematics notes that other strategies such as transit expansion may be needed to balance the Low-Cost bundle. Because this bundle was exclusively selected by cost, other important transportation concerns were neglected in some cases. For example, if compact development is not implemented together with transit expansion, there may negative effects such as congestion, reduced mobility, and equity concerns.[39] Because of these limitations of the Low-Cost bundle, it is recommended that if this bundle were used to guide selection of GHG reduction strategies, then transit expansion and increased transit services should be studied at a minimum, because, while they are capital-intensive, transit serves an important function in the overall transportation system.

4.3.2 The Long-Term/Maximum Results Strategy Bundle

The Long-Term/Maximum Results bundle achieves the maximum emissions reduction by 2050, making it interesting to policymakers who seek to achieve the long-term 2050 limit established in the Global Warming Solutions Act. It also offers a more robust transportation system overall, with the potential to address congestion, reduced mobility, and equity concerns posed by the Low-Cost bundle. Of the 24 strategies that were highlighted in this literature review, the Long-Term bundle roughly includes the following GHG reduction strategies, sorted from largest to smallest potential GHG reduction[40]:

---

[37] Cambridge Systematics, *Moving Cooler*, p. 62.
[38] Cambridge Systematics, *Moving Cooler*, pp. 72-73.
[39] Cambridge Systematics, *Moving Cooler*, pp. 62-63.
[40] Cambridge Systematics, *Moving Cooler*, p. 49.

- Driver education/eco-driving
- Compact development
- Reduced speed limits
- Congestion pricing
- Expansion of urban fixed-guideway transit
- Increased transit service
- Workplace TDM (general)
- Pedestrian improvements
- Transit fare reduction
- Bicycle improvements
- Rail freight infrastructure
- Parking management
- Car sharing

In addition to these strategies, the Long-term/Maximum Results bundle also names intercity tolls, intercity passenger rail expansion, high-speed passenger rail expansion, high-occupancy lanes, urban non-motorized zones and a number of strategies in two other categories—systems operations and management strategies and multimodal freight strategies. The systems operations and management strategies are:
- Freeway management (ramp metering, variable message signs, active traffic management, and integrated corridor management)
- Incident management, road weather management, signal management, traveler information, and vehicle infrastructure integration
- Bottleneck relief
- Highway capacity expansion

In addition to rail freight infrastructure, the other multimodal freight strategies are:
- Marine system improvements
- Shipping container permits
- Longer combination vehicle permits
- Weigh-in-motion screening
- Weigh-station bypass
- Truck-stop electrification
- Truck-only toll lanes
- Urban consolidation centers[41]

---

[41] Cambridge Systematics, *Moving Cooler*, p. 49.

Figure 4.6 demonstrates the reduction potential of these combined strategies at aggressive deployment, maximum deployment, and aggressive deployment with economy-wide pricing. Without economy-wide pricing, the figure shows that maximum deployment reduces GHG by four-to-six percent more than aggressive development, depending on the target year. Aggressive deployment with economy-wide pricing reduces GHG by eight-to-11 percent more than maximum deployment without economy-wide pricing.

FIGURE 4.6
National Transportation GHG Baseline: 1990, 2005, and Future Levels
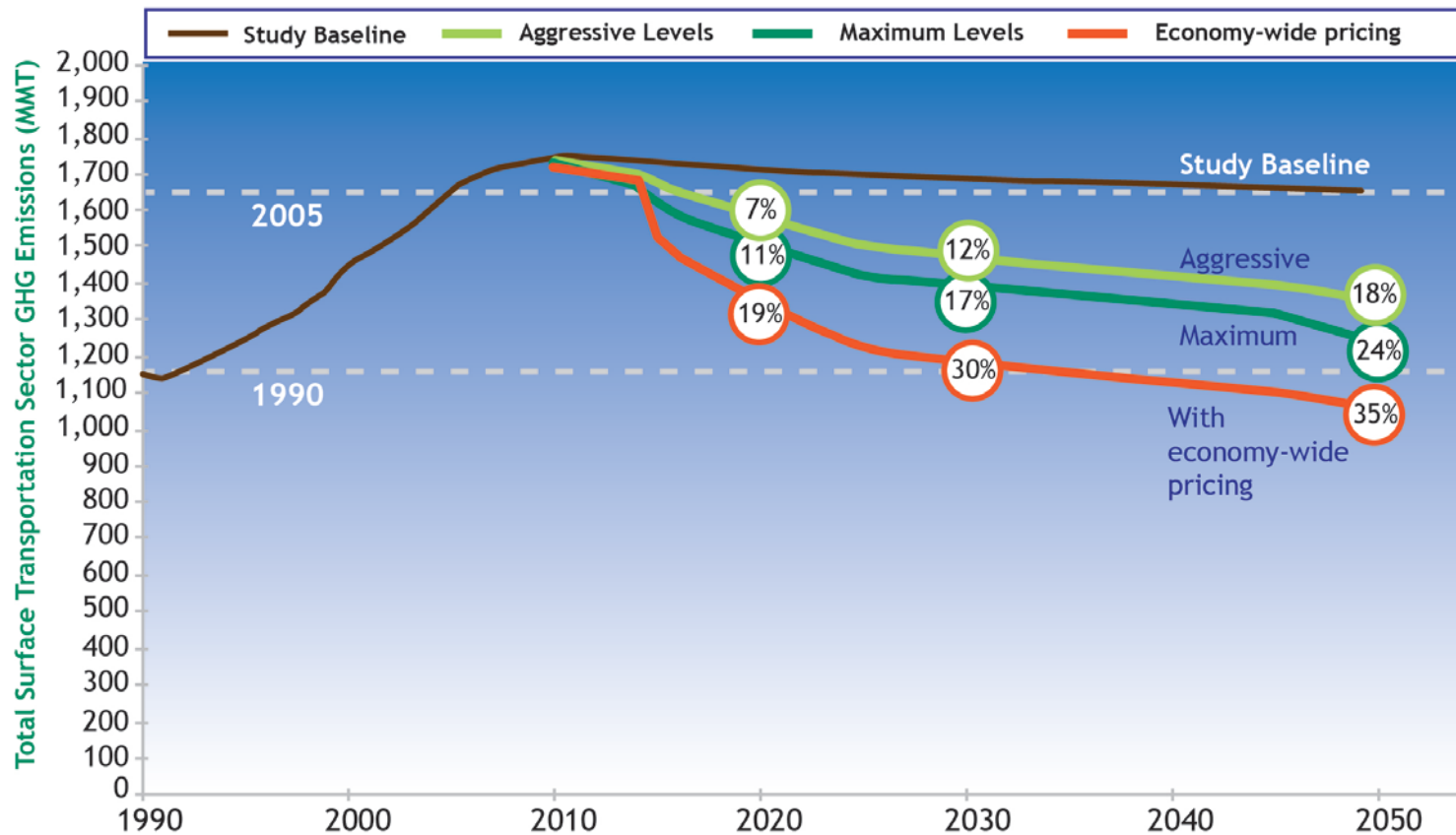
1990 and 2005 GHG Emissions - Combination of DOA AEO data and EPA GHG Inventory data
Study Baseline - Annual 1.4 percent VMT growth combined with 1.9 percent growth in fuel economy
Aggressive - GHG emissions from bundle deployed at aggressive level without economy-wide pricing measures
Maximum - GHG emissions from bundle deployed at maximum level without economy-wide pricing measures
Economy-Wide Pricing - Includes aggressive deployment of pay-as-you-drive (PAYD) insurance and both the VMT and fuel economy impact of the aggressive deployment of an indexed carbon price through 2050

Source: Cambridge Systematics, *Moving Cooler.*

The strategies in the Long-Term/Maximum Results combine to a 30-percent reduction from the national baseline in 2030. When exploring what these national data signify in Massachusetts with regard to the GWSA, there are two major differences. At the national level, emissions increased roughly 40 percent from 1990 to 2005, but in Massachusetts, emissions increased only 13 percent between the two baselines. While implementing all the strategies at the national level essentially brings 2030 emissions levels even with the 1990 levels, in Massachusetts the same reduction from all the strategies may bring emissions levels below 1990 levels if the 2030 Massachusetts baseline stays at 2005 levels, as it is projected to do at the national level. While no business-as-usual baseline has been projected yet for the Massachusetts transportation sector through 2030, data through 2012 show Massachusetts emissions have stayed at 2005 levels so far.

Again, the potential for each individual reduction strategy will also be different in Massachusetts than it will be at the national level. For example, some of the strategies apply only to urban areas or can achieve greater reductions in more urban areas compared to rural areas. Since Massachusetts is more urban and more densely developed than the nation on average, these types of strategies may yield greater reductions in the state and in the Boston region if they are implemented. Congestion pricing and transit fare reduction are two such strategies. Further study is needed to quantify the effects of each strategy.

4.4   QUESTIONABLE LONG RANGE SOLUTIONS

As noted in Table 3.1, several potential GHG reduction strategies have low or negative effects on greenhouse gas emissions when induced demand is taken into account and impacts are examined over the long term. Induced demand occurs when roadway capacity increases, and attracts more drivers; thus, total VMT may be higher than what would it would be otherwise. While these strategies have other benefits, their role in GHG reduction is limited.

4.4.1 Capacity Expansion and Bottleneck Relief

Two potential GHG reduction strategies—more aggressive capacity expansion and nationwide top 100 to 200 bottleneck relief—are noteworthy in that while they may decrease GHG emissions in the medium term (by 2030), they increase emissions in the long term (by 2050). In Massachusetts, in the context of the Global Warming Solutions Act's 2050 GHG emission reductions limit, these strategies are not effective emission solutions. Furthermore, capacity expansion and bottleneck relief are not cost-effective; not only are they costly to implement, but also their cost per metric ton of GHG reduced is high because of the lack of reductions achieved.

According to the methodology in *Moving Cooler,* which calculates impacts through 2050 and takes induced demand for future VMT into account, capacity expansion has a net effect of increasing greenhouse gas emissions. If increased user fees are put in place to pay for the capacity expansion, this strategy would have a net effect of increasing GHGs by four-to-15 MMTCO$_2$e. However, if no increased user fees were applied, this strategy would produce higher greenhouse gas emissions, from 440-to-560 MMTCO$_2$e, which is less than one percent of the *Moving Cooler* baseline. The Urban Land Institute notes that this result "underscores the importance of pricing strategies."[42] The Transportation Research Board adds that the cost-effectiveness of capacity expansion is undefined since net GHG benefits through 2050 were negative; GHG emissions increased rather than decreased.[43]

If only GHG impacts anticipated through 2030 are examined, as in Transportation Research Board's findings based on *Moving Cooler*'s calculations, capacity expansion of a 25-to-100 percent increase in economically justified investments above current levels results in a 0.07-to-0.29 percent emissions reduction in 2030. (Economically justified capacity expansion was based on analysis using the FHWA Highway Economic Requirements System (HERS) model.)[44]

Similarly, improving the top-100-to-200 bottlenecks nationwide by 2030 would result in a 0.05-to-0.21 percent emissions reduction in 2030. The moderate decreases in the medium term could mistakenly be interpreted as progress towards the long-term 2050 GHG reduction limit in a snapshot of the 2030 mid-point, despite increasing net emissions between 2010 and 2050. [45] These strategies emphasize that a long-term analysis that takes full account of long-term induced demand is needed to accompany short- and mid-term analysis.

4.4.2 Transportation System Management with Induced Demand

Transportation system management strategies are an important category of strategies that can be used to reduce greenhouse gas emissions. Transit system strategies such as improved headways and level-of-service (LOS), and truck system strategies such as idling reduction are examples of transportation system management strategies that can achieve moderate GHG reductions. Many roadway system-focused strategies, however, have little or no ability to reduce emissions once induced demand is included the analysis.

---

[42] Cambridge Systematics Inc., *Moving Cooler*, p. 41.
[43] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, p. 22-26.
[44] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, p. 22-26.
[45] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, p. 22-26.

Traffic management is one example of a strategy that reflects lower GHG emissions savings after induced demand is taken into account. The Transportation Research Board's analysis assumes deployment of traffic management strategies on freeways and arterials at the rate of 700-to-1,400 miles per year nationwide in locations of the greatest congestion. The TRB found that while large reductions of 0.89-to-1.3 percent were possible through reduced congestion, induced demand occurring on less congested roads consumed most of the savings, for net reductions of only 0.07-to-0.08 percent.[46]

Other transportation system management strategies that do not significantly reduce greenhouse gas emissions are presented in Table 4.3, below.[47]

TABLE 4.3
Transportation System Management Strategies with Limited Potential

Strategy Name	Description	GHG Reduction (2030) before Induced Demand	Actual GHG Reduction (2030)
Signal control management	Upgrade to closed loop or traffic adaptive system	0.01–0.10%	0.00%
Real time traffic information	511, USDOT website, personalized information	0.02–0.07%	0.00%
Ramp metering	Centrally controlled	0.12–0.22%	0.01%
Active traffic management	Speed harmonization, lane control, queue warning, hard shoulder running	0.24–0.29%	0.01-0.02%
Integrated corridor management	Multiple strategies	0.24–0.29%	0.01-0.02%
Incident management	Detection and response, including coordination through traffic management center	0.24–0.34%	0.02-0.03%

Source: Transportation Research Board, Incorporating Greenhouse Gas Emissions.

---

[46] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, p. 22-26.
[47] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, p. 22-26.

4.5   GHG REDUCTION STRATEGY CONCLUSIONS

4.5.1 Economy-Wide Pricing

Ultimately, economy-wide pricing is critical to achieving the greatest greenhouse gas emission reductions. It may be difficult to bring Massachusetts transportation emissions below 1990 levels and help the state reach the Global Warming Solutions Act limits, particularly the more ambitious 2050 limits, without adopting economy-wide pricing strategies such as a carbon tax and/or cap-and-trade.

See the call out box to the right for details of how a price on carbon could be implemented in Massachusetts.[48,49]

To illustrate the effect of economy-wide pricing, Table 4.4 below shows the effect of including economy-wide pricing measures in the Low-Cost strategy bundle in terms of percentage increase in cumulative GHG reduction effect from 2010 through 2050. Note that that effect of the baseline Low-Cost bundle at maximum deployment is 26 percent higher than the effect at aggressive deployment; the level of deployment plays a crucial role as well.[50]

> **Carbon Pricing in Massachusetts**
>
> A draft of bill S.1747, An Act Combating Climate Change, was introduced in fall 2015 and shows how Massachusetts could adopt a price on carbon. The Act aims to levy fees on fuels that emit CO_2, which would drive demand and emissions down. The Act would distribute the proceeds of the fee equally to everyone through a rebate, which would avoid raising taxes. Residents who use more energy than average would pay more in fees than they get back in rebates. Most residents (the bottom 60 percent) would actually get rebates. Fees would be set at $10 per ton of CO_2 in the first year and increase $5 per ton each year until they reach $40 per ton.

---

[48] Senator Mike Barret, An Act Combating Climate Change: the basics, 2015, http://senatormikebarrett.com/wp-content/uploads/2015/10/Carbon-Pricing-the-basics.pdf.

[49] The 189th General Court of Massachusetts, Bill S.1747, 2015, https://malegislature.gov/Bills/189/Senate/S1747.

[50] Cambridge Systematics, *Moving Cooler*, pp. 72-73.

TABLE 4.4
Impacts of Economy-Wide Pricing Measures upon the Low Cost Strategy
Bundle at Aggressive and Maximum Deployment

Strategy Bundle	Aggressive Deployment: Percent increase in Cumulative Effect (2010–2050)	Maximum Deployment: Percent increase in Cumulative Effect (2010–2050)
Low-Cost Bundle	--	--
Bundle + PAYD	18%	22%
Bundle + PAYD + VMT Fees	28%	57%
Bundle + VMT Effect of Carbon Price	10%	50%
Bundle + VMT effect of Carbon Price + MPG effect of Carbon Price	53%	157%

MPG = Miles per gallon. PAYD = Pay-As-You-Drive Insurance. VMT = Vehicle-miles traveled.
Source: Cambridge Systematics, *Moving Cooler*

Ultimately, the MPO cannot implement economy-wide pricing strategies; it can only advocate for these strategies.

4.5.2 Public Transportation Improvements

Of the MPO-fundable strategies, improvements to public transportation through expansion of urban fixed-guideway transit and increased transit service have the potential to achieve relatively large GHG reductions. Many reports suggest that investment in transit could play a significant role in efforts to reduce GHG emissions by shifting travelers to more efficient modes of transportation. *Moving Cooler* makes this point: "Transit investments may be particularly critical if significant pricing strategies are in place, to provide travelers a viable, lower cost alternative to driving."[51] Transit also importantly ties in to land-use strategies and compact development. Transit-oriented development projects nationwide have been found to generate 44 percent fewer weekday vehicle trips, on average, than the amounts estimated by the Institute for Transportation Engineers.[52]

Although transit infrastructure and service improvements have low cost-effectiveness per ton of GHG reduced for the implementing agency, these strategies can yield net savings overall because of large reduced personal vehicle operating costs for users.

---

[51] Cambridge Systematics Inc., *Moving Cooler*, p. 42.
[52] Transportation Research Board, Transit Cooperative Research Program, *Effects of TOD on Housing, Parking, and Travel*, 2008, Washington, D.C., http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_rpt_128.pdf (accessed March 20, 2015).

Ridership is an important factor in determining the cost-effectiveness and benefits of specific projects, which could be negative if ridership is low.[53]

Public transportation can provide equity benefits in the Boston region by alleviating part of any mobility loss because of pricing measures. Strategies that improve public transportation can provide a higher proportion of benefits to lower-income groups since these groups rely more on public transportation than other groups. Similarly, this strategy will provide a higher proportion of benefits to other groups with fewer transportation mode choices, such as those who reside in rural areas and individuals without access to automobiles.[54] However, rising property values and rent increases associated with transit improvements can potentially result in displacement of lower-income residents; housing measures may be needed to ensure the most equitable outcomes.[55]

Transit has been linked to improved job access, access to educational opportunities (in this way supporting increased employment), and access to preventative health care. Following the start of new transit services, increased job participation has been found for low-wage workers, demonstrating the critical role transit can play in employment opportunities. Improved access to preventative health care can help individuals avoid the need for costlier emergency care visits, resulting in cost savings.[56]

4.5.3 Healthy Transportation Improvements

Improvements to pedestrian and bicycle accommodations are two other MPO-fundable strategies that are beneficial in multiple ways. In addition to supporting GHG reduction, they have public health and safety benefits and are cost-effective. Both modes also can generate equity benefits. *Moving Cooler* states that investment in pedestrian and bicycle modes "can have substantial positive equity effects by increasing mobility for lower income groups and those without significant access to vehicles." Persons without significant access to vehicles include youth, the elderly, disabled persons, lower income individuals, or individuals without driver permits.

---

[53] Transportation Research Board, *Incorporating Greenhouse Gas Emissions*, p. 33-34.

[54] Cambridge Systematics Inc., *Moving Cooler*, p. 74.

[55] Dukakis Center for Urban and Regional Policy, Northeastern University, Maintaining Diversity in America's Transit-Rich Neighborhoods: Tools for Equitable Neighborhood Change, http://www.northeastern.edu/dukakiscenter/transportation/transit-oriented-development/maintaining-diversity-in-americas-transit-rich-neighborhoods/ (accessed March 25, 2014).

[56] National Cooperative Highway Research Program, Selected Indirect Benefits of State Investment in Public Transportation, Research Results Digest 393, http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rrd_393.pdf.

Having walking and bicycling as newly available transportation options would enhance the ability of individuals in these groups to access needed services.[57]

Bicycle and pedestrian strategies also are cost-effective in terms of reducing GHG emissions. These modes offer substantial vehicle cost savings; when the costs of implementation are considered together with vehicle cost savings for users, there are net savings of $600 to $700 per $MTCO_2$.[58]

These strategies also generate benefits in terms of increased physical activity and improved public health. Around 70 percent of American adults do not achieve recommended levels of physical activity, and sedentary lifestyles are associated with the rapid increase in the percentage of Americans that are overweight and obese. Environments that are unsafe for walking and biking influence decisions not to choose these transportation options. However, if these modes can be made safer and allow more people to walk and bike, a great health benefit could be realized.[59,60]

Pedestrian and bicycle improvements, like transit, benefit from the presence of compact development. These non-motorized modes support transit use by making connections to and from transit stops, and, like transit, are "much more effective" where destinations are close together in densely developed areas.[61]

4.5.4 Workplace-Focused Strategies

Many of the MPO-fundable GHG reduction strategies target greenhouse gas emissions associated with the workplace. Teleworking has the third-greatest potential of the MPO-fundable strategies and workplace TDM has the fifth-greatest potential. The ride matching, carpooling, and vanpooling strategy can also help to reduce workplace emissions.

Quality of life and mobility also may be gained from workplace-focused GHG reduction strategies. Benefits of teleworking identified by the Environmental Protection Agency (EPA) and Congress include "enhanced worker productivity and morale, improved employee attraction and retention, and reduced overhead

---

[57] Cambridge Systematics Inc., *Moving Cooler*, p. 74.

[58] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-49, 5-53.

[59] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, p. 5-49, 5-53.

[60] Centers for Disease Control and Prevention, "Obesity and Overweight," http://www.cdc.gov/nchs/fastats/obesity-overweight.htm (accessed March 6, 2015).

[61] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-6.

 expenses." Telework also can enhance mobility and productivity of travel (working during transit travel). [62]

Workplace-focused strategies can offer net savings. General workplace TDM has been found to result in large vehicle cost savings for employees.[63] Carpool programs realize a net savings when private vehicle operating costs are included in cost-effectiveness. Vanpool programs likewise can cover most, if not all, of their purchase, operating, and administrative costs through subscription fees, as individuals save on vehicle operating costs. [64]

---

[62] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-77, 5-81.

[63] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-74, 5-77.

[64] Cambridge Systematics and Eastern Research Group, *Transportation's Role*, pp. 5-87, 5-91.

Chapter 5—Inventory and Evaluation of MPO Investments

5.1   MPO INVESTMENT PROGRAMS

The MPO recently adopted its LRTP, *Charting Progress to 2040,* which includes funding for maintenance and expansion of the region's transportation system under different investment programs. As part of the LRTP development, the MPO conducted a scenario planning process to help finalize its goals and objectives and determine how best to program their funding to meet those goals and objectives through different investment programs. The goal categories are:

- Safety
- System Preservation
- Capacity Management/Mobility
- Clean Air and Clean Communities
- Transportation Equity
- Economic Vitality

The MPO uses its goals and associated objectives to evaluate and rank projects and programs to be funded over the next 25 years in its LRTP and more specifically over the next five years in the TIP. As shown above, the MPO's Clean Air and Clean Communities is one of six goal areas. This goal addresses the reduction of GHG emissions. The MPO considers all goal areas when deciding which projects will be programmed in the LRTP and TIP. The goal areas also are used when considering studies that will be performed as part of the MPO's annual UPWP.

The MPO chose to program its LRTP using a set of investment programs as shown in Figure 5.1.

FIGURE 5.1
MPO LRTP Funding for Investment Programs
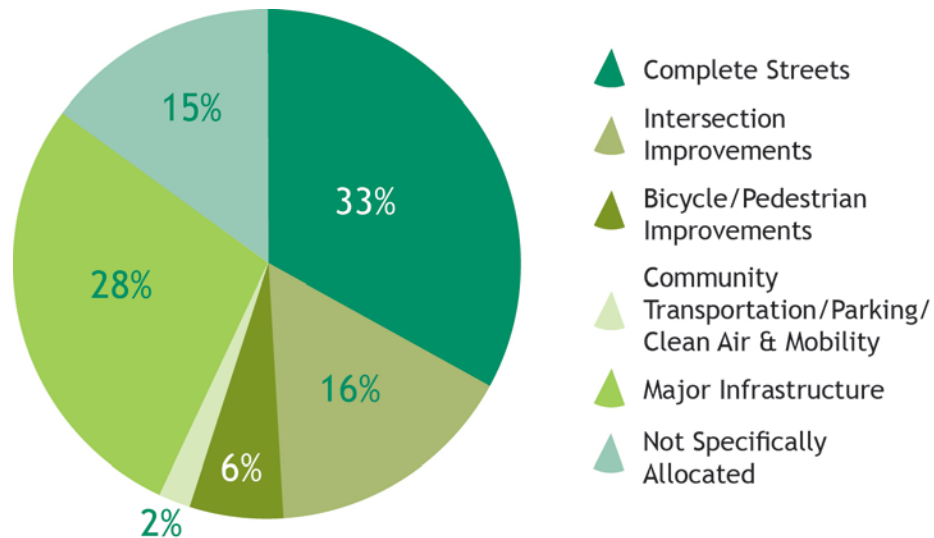
Source: Central Transportation Planning Staff.

As discussed in Section 2.1.1, several of these investment programs—including Intersection Improvements, Complete Streets, Bicycle Network and Pedestrian Connections, Community Transportation and Parking, and transit projects included in the Major Infrastructure category—relate directly to the MPO's Clean Air/Clean Communities goal with its objective of reducing GHG emissions.

Many of the projects that have been funded in past TIPs fall into the Intersections Improvements, Complete Streets, and Bicycle and Pedestrian improvements programs. Shuttle services have been funded in the past under older Suburban Mobility and Clean Air and Mobility programs. Any new shuttle service projects would now fall into the new Community Transportation investment program. The MPO flexed highway funding to major infrastructure transit projects, including the completed Assembly Square MBTA station and to the proposed Green Line Phase II project extending the Green Line from College Avenue in Somerville to Mystic Valley Parkway in Medford.

As part of this study, MPO staff inventoried projects that have been funded, studied, or analyzed by the MPO, according to investment category. Projects in each investment category then were compared to determine the projected range of GHG reductions within that investment category. GHG emissions were calculated as reductions in CO_2 for this analysis. The reductions can be calculated in different ways, whether using the travel demand model or through off-model calculations.

Calculation methodologies are described in the next section, followed by the GHG impacts and cost-effectiveness of the different MPO investment programs.

5.2   EXISTING AND PROPOSED GHG EMISSIONS CALCULATION TOOLS

5.2.1 Existing GHG Emissions Calculation Tools

The MPO's regional travel demand model has the ability to forecast GHG emissions associated with highway and transit major infrastructure projects. In order for the travel-demand model to be effective, the project must meet certain capacity-adding characteristics, change the network connectivity, alter tolling structure, or change use policies such as a high-occupancy-vehicle lane. For highway projects, this could include added connectivity or increased capacity changes to the transportation network. For transit projects, it can include new transit stations, lines, or parking facilities. Other characteristics could be changes to fares, travel times, or frequency.

In addition to capacity-adding projects, it is also important to monitor and evaluate the GHG impacts of other projects that do not have these characteristics, including maintenance and operations projects. In order to monitor and evaluate the impacts of these projects, MassDOT and the MPOs developed spreadsheet analysis approaches for identifying the anticipated emission impacts of different project types. The data and analysis required by MPO staff to conduct these calculations using the spreadsheet analysis is typically derived from functional design reports submitted for projects at the 25 percent design phase.

All calculations, whether analyzed using the travel-demand model or the spreadsheet analysis approach, used the same emission factors to provide equitable comparisons. Emission factors used for calculating emissions changes were determined using the EPA's latest emissions model, Motor Vehicle Emissions Simulator (MOVES) 2014 for passenger vehicles and trucks. Transit vehicle emissions were obtained from FTA and EPA guidance documents. MOVES 2014 requires a wide range of input parameters, including inspection and maintenance program information and other data, such as fuel formulation and supply, speed distribution, vehicle fleet mix, and fleet age distribution. Inputs used for this analysis were received from the Massachusetts Department of Environmental Protection; and include information about programs that were submitted to the EPA as the strategy for the Commonwealth to attain ambient air-quality standards.

Intersection Improvements

An intersection reconstruction or signalization project typically reduces delays and idling, therefore reducing GHG emissions.

- Step 1: Calculate the AM-peak-hour total intersection delay (in seconds)
- Step 2: Calculate the PM-peak-hour total intersection delay (in seconds)
- Step 3: Select the peak hour with the longer intersection delay
- Step 4: Calculate the selected peak-hour total intersection delay with improvements
- Step 5: Calculate the vehicle delay in hours per day (assumes peak-hour delay is 10 percent of daily delay)
- Step 6: Input the MOVES emission factors for arterial idling speed
- Step 7: Calculate the net emissions change in kilograms per day
- Step 8: Calculate the net emissions change in kilograms per year (seasonally adjusted)
- Step 9: Calculate the cost-effectiveness (first year cost per kilogram of emissions reduced)

Complete Streets

Complete Streets projects can increase transportation options by adding new sidewalks and bicycle facilities. They also may include roadway and intersection reconstruction or signalization projects within a corridor that typically reduce delays and idling, therefore reducing GHG emissions. Roadway improvements may also help to improve transit operations in the corridor. The following steps calculate the sidewalk and bicycle benefits of the project. The steps outlined above under Intersection Improvements are performed if the project includes them.

- Step 1: Calculate the estimated number of one-way bicycle and walk miles of travel based on the population residing in the communities of the facilities service area and the communities' bicycle and pedestrian commuter mode share
- Step 2: Calculate the reduction in vehicle miles traveled per day and per year (assumes the facility operates 365 days per year)
- Step 3: Input the MOVES emission factors for the average commuter travel speed (assumes 35 mph)
- Step 4: Calculate the net emissions change in kilograms per year (seasonally adjusted)
- Step 5: Calculate the cost-effectiveness (first year cost per kilogram of emissions reduced)

Calculations also were performed on the following project types in previous TIPs; however there are no projects of these types in the current FFY 2016–2020 TIP.

Pedestrian and Bicycle Infrastructure

A shared-use path that would enable increased walking and biking and reduced automobile trips.
- Step 1: Calculate the estimated number of one-way trips based on the percentage of workers residing in the communities of the facilities' service area and the communities' bicycle and pedestrian commuter mode share
- Step 2: Calculate the reduction in vehicle miles traveled per day and per year (assumes each trip is the length of the facility; assumes the facility operates 200 days per year)
- Step 3: Input the MOBILE 6/MOVES emission factors for the average commuter travel speed (assumes 35 mph)
- Step 4: Calculate the net emissions change in kilograms per year (seasonally adjusted)
- Step 5: Calculate the cost-effectiveness (first year cost per kilogram of emissions reduced)

New and Additional Transit Service

A new bus or shuttle service that reduces automobile trips.
- Step 1: Determine vehicle emission rates for automobiles operating at 35 mph and the new bus operated at 30 mph
- Step 2: Calculate vehicle miles traveled and emission savings from the private automobile
- Step 3: Calculate the bus route miles and emissions for the new bus route
- Step 4: Add the impact of the new bus emissions to the emissions from private automobiles
- Step 5: Calculate the net emissions change in kilograms per year (seasonally adjusted)
- Step 6: Calculate the cost-effectiveness (first year cost per kilogram of emissions reduced)

Park-and-Ride Lot

A facility that reduces automobile trips by encouraging HOV travel through carpooling or transit.
- Step 1: Establish number of parking spaces with average utilization rate (the default average utilization rate is 85%)
- Step 2: Determine the mode split of future users prior to lot construction (drive alone, carpool/vanpool, walk/bicycle/transit/other) and the future mode split of those leaving the lot (carpool/vanpool, transit, walk/bicycle/transit/other)
- Step 3: Determine distance to primary employment center and average peak hour travel speed (35 mph is the default travel speed)
- Step 4: Calculate existing conditions and future conditions
- Step 5: Calculate the net emissions change in kilograms per year (seasonally adjusted)

- Step 6: Calculate the cost-effectiveness (first year cost per kilogram of emissions reduced)

Bus Replacement

A new bus that replaces an old bus with newer, cleaner technology.
- Step 1: Determine emission rates for the existing bus and the new bus purchase
- Step 2: Calculate the fleet vehicle miles per day
- Step 3: Calculate the net emissions change in kilograms per year (default operating days per year is 301)
- Step 4: Calculate the cost-effectiveness (default bus life is 12 years)

5.2.2 Proposed GHG Emission Calculation Tools

MassDOT SHRP2 GHG Tool and Process Evaluation Project

The MPO currently uses the tools described above (the travel demand model for regionally significant projects and the spreadsheet analysis for the smaller projects) to calculate a project's impact on GHG emissions in the region. MassDOT recently received Strategic Highway Research Program (SHRP2) funding from the Federal Highway Administration (FHWA) to address how MassDOT and the MPOs estimate project-related GHG emissions and how those outputs inform planning and the project selection process. This funding will support MassDOT, in collaboration with the MPOs, to identify new tools and develop practices to help the Commonwealth to comply with federal and state laws.

MassDOT identified the challenges to be addressed by this project, including:
- MassDOT's statewide GHG projection modeling tool is resource intensive and runs only every four years, making it challenging to produce timely projections of transportation sector emissions.
- MPOs are required to assess and consider the GHG impacts of the LRTPs and TIPs, including the projects within these plans, but MPOs have variable capacities for using the tools available to fulfill this requirement.
- It can be difficult to estimate GHG impacts early enough in the project development process to have meaningful data to affect project selection.
- MassDOT does not have an established system for assessing the GHG impacts of its highway maintenance activities nor a method by which GHG impacts of maintenance are considered in decision-making processes.
- This project presents an opportunity to improve the consideration of GHG emissions in freight planning.

The MassDOT study will review and evaluate how MassDOT and MPOs estimate project-level and statewide GHG emissions with two goals:

- Ensure the early-stage project development and selection processes, including those for highway maintenance activities, utilize the most appropriate methods for estimating and considering GHG impacts of projects, in order to assist MPOs and MassDOT in meeting all requirements under the Global Warming Solutions Act
- Improve methods of forecasting transportation sector GHG emissions in Massachusetts, and support the further development of data-driven plans, strategies, and targets

The MassDOT study also will review how MassDOT coordinates with MPOs to measure and track progress toward reaching GHG goals using performance measures. This effort will assist MassDOT in complying with reporting requirements under the Global Warming Solutions Act, and will prepare MassDOT for the performance management requirements under MAP-21 and Fixing America's Surface Transportation (FAST) Act.

Energy and Emissions Reduction Policy Analysis (EERPAT) Tool

The FHWA developed the Energy and Emissions Reduction Policy Analysis (EERPAT) tool to compare, contrast, and analyze various GHG reduction policy scenarios for the state's transportation sector. This tool estimates GHG emissions from surface transportation, including fuel usage (and electricity usage for battery charging) by autos, light trucks, transit vehicles, and heavy trucks.

The EERPAT tool is a policy analysis tool that complements tools such as the EPA's MOVES (described earlier) by providing a rapid analysis of many scenarios that combine effects of various policy and transportation system changes. It was developed to address a wide range of factors, from changes in population demographics, land use characteristics, transportation supply, vehicle fleet characteristics, demand management programs, effects of pricing and congestion, through to the carbon intensity of fuels and electric power generation.

MassDOT is currently working with FHWA as part of a pilot program using the EERPAT tool to evaluate different strategies to reduce GHG emissions in the Commonwealth. Part of the pilot program includes training MassDOT, MPOs, and regional planning agency staff in applying EERPAT to support GHG strategy analysis and policy making.

5.3   GHG IMPACTS AND COST-EFFECTIVENESS OF MPO INVESTMENTS

As discussed in section 4.2, GHG emissions can be estimated for projects in the MPO's investment programs using the travel demand model for highway and transit major infrastructure projects that meet certain capacity-adding

characteristics. The majority of capacity-adding projects funded by the MPO have been analyzed as a bundle as part of the LRTP using the travel demand model, a procedure that does not allow staff to associate a GHG reduction with a particular project. Select major infrastructure projects have been analyzed for GHG benefits if a project level analysis was performed by CTPS as part of work done for the various transportation agencies. This work used a variety of emission factors developed through older emission models. More recent work is underway; however that work was not completed in time to include it in this report.

Given the lack of availability of comparable data from the regional model, this cost-effectiveness analysis will focus on the projects that have been analyzed using the CMAQ spreadsheets described in section 4.2. The analyses included projects that were funded in the TIP under the MPO's four investment programs:

- Complete Streets
- Intersection Improvements
- Bicycle and Pedestrian
- Shuttle Bus Services (funded under the former Suburban Mobility or Clean Air and Mobility programs)

A description of other projects that do not fit into one of these investment programs is also included.

5.3.1 Roadway and Multi-Use Path Improvements

Comparing Transportation and Non-Transportation Projects

As discussed earlier, transportation is a major source of GHG emissions. Chapter 4—Promising Strategies for Reducing GHG Emissions Identified in the Literature Review, ranked strategies on their effectiveness to reduce GHG emissions. The most effective strategies include those with economy-wide pricing such as carbon taxes, congestion pricing, and pay-as-you-drive insurance; however, the MPO has no authority over implementing these strategies. The projects for which the MPO has funding authority include roadway operation, pedestrian, and bicycle improvements. The projects fall into the MPO's Complete Streets, intersection, and bicycle and pedestrian investment programs. These types of projects rank lower among the strategies reviewed in Chapter 3 but they do provide measurable GHG benefits.

Although these types of projects rank lower for GHG benefits they can, however, affect the success of other strategies, or are important for balancing equity and other needs of the transportation system as a whole. For example, if congestion pricing increases the cost of driving in order to discourage single-occupancy vehicles, there needs to be safe and comfortable alternative transportation choices available to former drivers, such as transit, walking and biking. For those

that do continue to drive, improving roadway operations, especially at intersections will help to reduce GHG emissions. Projects with lower GHG impacts can offer other significant benefits including mobility, safety, and livability.

Analytical Approach

Project Comparisons by Community Type

Staff reviewed projects that were funded and/or analyzed by the MPO for their GHG benefits during the TIP development. These 51 projects are described below. The projects were distributed into the four Metropolitan Area Planning Council (MAPC) community-type groups, shown in Figure 5.1, to identify the different density and usage characteristics of the projects. MAPC classified each of the 101 municipalities in the MPO region into four community types, based on existing development patterns and growth potential.

- Inner Core: High-density built-out communities in the center of the region with multi-family homes as a significant portion of housing stock, and employment concentrated in Downtown Boston and portions of Cambridge. The Inner Core is essentially "built-out," with little vacant developable land.
- Regional Urban Centers: Communities outside the inner core with urban-scale downtown centers, moderately dense residential neighborhoods, a mixture of built-out areas and developable land on the periphery, as well as growing immigrant populations.
- Maturing Suburbs: Moderately dense communities with less than 20 percent of land vacant and developable. These communities are comprised mainly of owner-occupied single-family homes, and are mainly residential, although some are significant employment centers.
- Developing Suburbs: Communities with large expanses of vacant developable land, ranging from those with strong town centers and moderately dense neighborhoods to ones that are more rural.

FIGURE 5.2
Metropolitan Area Planning Council
Community Types
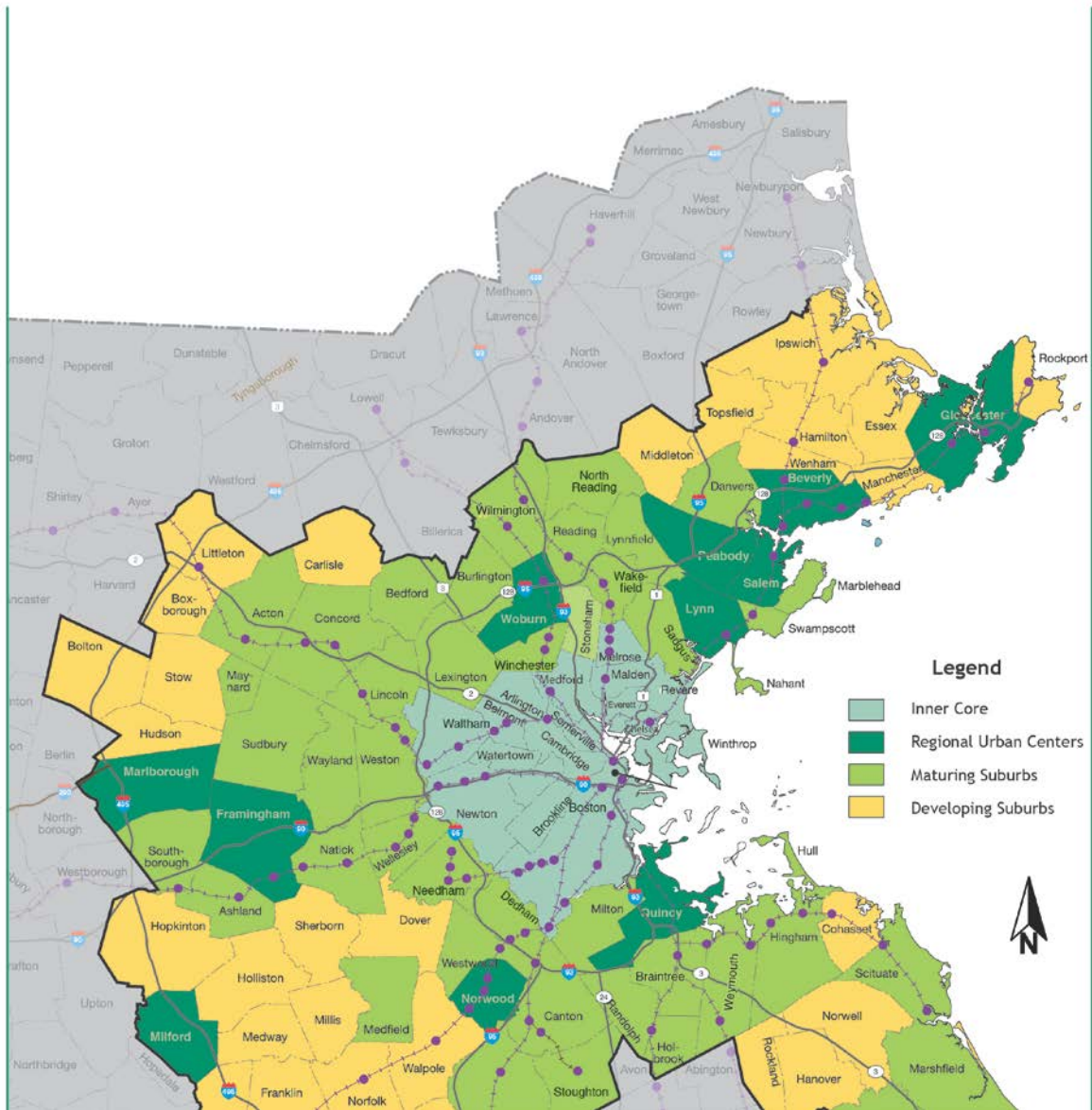
Results by Community Type

The expected GHG reduction from a particular roadway project depends on many factors including how a roadway is used, the proposed improvement, and the amount of traffic in the area. The following information shows predicted changes in GHG emissions for 51 Complete Streets and Intersection roadway projects funded or analyzed by MPO staff.

Each roadway project is characterized by three values:
- Estimated cost of project
- Lane-miles of roadway being rebuilt or reconfigured
- Predicted annual GHG reduction in tons

From these three values, staff formed three ratios, which serve as the basis of comparison between the individual projects as well as between groups of projects defined by community type as described above. The data and ratios are shown in Table 5.1.

Within each community-type group, the projects are listed in descending order of GHG reduction per lane-mile. This column reflects how inefficiently the existing traffic within each project area is currently accommodated and the magnitude of improvement that could be expected for each proposed project. In a very few instances, the overall GHG emissions from a project are predicted to increase, and these GHG increases are reflected as negative values in the appropriate columns.

In Table 5.1, a general location is provided for each project, then three major project characteristics: estimated project cost, lane-miles of construction, and projected annual tons of GHG reduction.

The next three columns show three ratios calculated from the project characteristics:
- Cost per lane-mile
- Cost per ton of annual GHG reduction
- Tons of GHG reduction/increase per lane-mile

The extent of a proposed improvement is suggested by the number of lane-miles. These projects do not involve major bridge construction, and the cost per lane-mile roughly reflects factors such as construction difficulty, land takings, and expenses of constructing associated streetscape elements.

TABLE 5.1
Projected Greenhouse Gas Reductions
Projects Grouped by Community Type
(All Costs are in Thousands of Dollars)
(All Tons are Tons per Year)

General Location	Cost	Lane-Miles	Tons GHG	Cost per Lane-Mile	Cost per Ton	Tons per Lane-Mile
Boston - Boylston St. in Fenway	$6,555	2.52	1,963	$2,601	$3	779
Cambridge and Somerville - Beacon St.	9,088	2.20	754	4,131	12	343
Melrose - Lebanon St.	4,063	1.54	426	2,638	10	277
Arlington - Massachusetts Ave.	5,978	2.08	295	2,874	20	142
Everett - Ferry St.	6,440	3.26	458	1,975	14	140
Boston - Commonwealth Ave. near B.U.	19,180	1.96	179	9,786	107	91
Belmont and Watertown - Trapelo Rd.	13,604	5.06	314	2,689	43	62
Brookline - Brookline Village	5,070	1.56	73	3,250	69	47
Boston - 10 signal improvements	4,654	1.54	59	3,022	79	38
Newton - Walnut St.	4,648	2.54	21	1,830	-216	-8
Inner Core Group	**$79,280**	**24.26**	**4,499**	**$3,268**	**$18**	**185**
Quincy - Quincy Ave.	$1,257	0.20	602	$6,285	$2	3,009
Quincy - Hancock St.	3,891	0.14	417	27,793	9	2,975
Framingham - Route 126	8,791	1.44	924	6,105	10	642
Marlborough - Route 20 at Concord Rd.	1,707	.32	156	5,334	11	486
Lynn - Route 129 (part)	4,291	1.22	419	3,517	10	343
Lynn - Route 129 (part)	3,458	1.44	425	2,401	8	295
Marlborough - Route 85	5,144	2.28	650	2,256	8	285
Norwood Route 1A	3,275	.40	74	8,188	44	185
Beverly - Route 1A	19,874	4.08	723	4,871	27	177
Milford - Route 16	2,800	1.20	206	2,333	14	171
Quincy - Adams Green	7,911	.94	137	8,416	58	146
Woburn - Montvale Ave.	4,225	1.48	109	2,855	39	74
Salem - Canal St.	7,852	2.44	177	3,218	44	72
Marlborough - US Route 20	2,253	.60	20	3,755	112	34
Gloucester - Washington St.	4,600	2.64	30	1,742	154	11
Regional Centers Group	**$81,329**	**20.82**	**5,068**	**$3,906**	**$16**	**243**

General Location	Cost	Lane-Miles	Tons GHG	Cost per Lane-Mile	Cost per Ton	Tons per Lane-Mile
Holbrook - Weymouth St. at Pine St.	$1,017	0.20	247	$5,085	$4	1,236
Natick & Wellesley - Route 9 at Oak St.	5,810	1.86	2,146	3,124	3	1,154
Wayland - Route 27 at Route 30	2,479	0.20	226	12,395	11	1,130
Winchester - Route 3	2,014	0.74	542	2,722	4	733
Duxbury - Route 53 at Winter St.	1,107	0.20	57	5,535	20	283
Weston - Route 30 at Wellesley St.	2,429	1.06	236	2,292	10	223
Duxbury - Route 3A at Route 3	2,400	1.06	162	2,264	15	153
Southborough - Route 30	6,345	1.80	235	3,525	27	131
Lexington - Massachusetts Ave.	5,200	1.46	190	3,562	27	130
Hingham - Derby St.	3,841	3.32	388	1,157	10	117
Needham and Newton - Highland Ave.	14,298	9.15	804	1,563	18	88
Danvers - Collins St.	7,300	1.80	154	4,056	48	85
Weymouth - Libbey Industrial Pkwy.	937	0.20	15	4,685	63	74
Ashland - Route 126	13,277	3.42	155	3,882	86	45
Natick - Route 127	13,091	4.36	196	3,003	67	45
Reading - West St.	6,978	3.24	79	2,154	88	24
Hull - Atlantic Ave.	5,175	2.50	8	2,070	638	3
Holbrook - Route 139	2,471	1.74	5	1,420	547	3
Hingham - Derby St. at Route 53	2,827	0.76	-125	3,720	-23	-165
Maturing Suburbs Group	**$98,996**	**39.07**	**5,721**	**$2,534**	**$17**	**146**
Hopkinton - Route 135	7,235	1.64	1,317	4,412	5	803
Medway - Route 109	12,063	4.50	780	2,681	15	173
Walpole - Route 1A	15,886	4.66	237	3,409	67	51
Franklin - Route 140	5,120	2.54	77	2,016	66	30
Ipswich - Central and S. Main streets	2,624	1.10	5	2,385	577	4
Franklin - Pleasant St.	5,379	4.80	15	1,121	356	3
Wrentham - Route 152	3,946	1.78	2	2,217	2,294	1
Developing Suburbs Group	**$52,253**	**21.02**	**2,433**	**$2,486**	**$21**	**116**

Source: Central Transportation Planning Staff.

The cost per ton of GHG reduction varies widely, much more so than the construction cost per lane-mile. As can be observed throughout Table 5.1, the projects that substantially improve a roadway's efficiency, as reflected in the right-most column, tend also to be cost-effective with a low cost per ton of GHG reduction.

At the bottom of each group of projects are totals of the three characteristic values for each group, as well as three group average ratios. The projects within each group show a wide range of cost-effectiveness and opportunity to improve roadway efficiency. However, the group averages also exhibit some meaningful differences.

The top of Table 5.1 shows the Inner Core and Regional Centers communities. Construction costs per lane-mile are higher for these project groups than for the Maturing Suburbs and Developing Suburbs project groups shown at the bottom of Table 5.1. However, the average tons reduction per lane-mile is greater for both the Inner Core and Regional Centers than for the Maturing and Developing suburbs. Both of these differences are because of the higher density of these more urbanized communities. Higher urban density usually implies higher construction costs as well as higher traffic volumes funneling through inefficient roadway subsystems.

The higher average construction costs and efficiency benefit of the urbanized groups roughly balance out, and the average cost per ton of annual GHG reduction is similar for the Inner Core, Regional Centers, and Maturing Suburbs. The lower average cost-effectiveness in the Developing Suburbs, $21,000 per ton, may because of lower traffic volumes in these communities.

Comparing Types of Programs

All but two of the 51 projects shown in Table 5.1 would be funded through two distinct investment programs. There are 14 projects where the proposed investment is focused on the reconstruction of a specific intersection, and the characteristic values of these projects have been summed and the relevant ratios calculated, as shown in "Intersections Program" in Table 5.2.

There are 35 projects in Table 5.1 that are classified as "Complete Streets" projects, and their project totals and ratios as shown in Table 5.2. The Complete Streets projects can include one or more intersections along the improved roadway such as bicycle and pedestrian improvements. Taken altogether, these 35 projects have almost ten times the lane-miles as the 14 intersection projects.

TABLE 5.2
Projected Greenhouse Gas Reductions by Type of Investment Program
(All Costs are Thousands of Dollars)
(All Tons are Tons/Year)

Type of Program	Cost	Lane-Miles	Tons GHG	Cost per Lane-mile	Cost per Ton	Tons per Lane-Mile
Intersections	$35,804	8.88	4,813	$4,032	$7	542
Complete Streets	257,531	85.66	11,995	3,006	21	140
Multi-use Paths	41,174	21.80	1,055	1,889	39	48
All Programs	**$334,509**	**107.46**	**13,050**	**$3,113**	**$26**	**121**

Source: Central Transportation Planning Staff.

Table 5.2 also includes an analysis for a group of seven multi-use projects, not included in Table 5.1. These "multi-use paths" are used by pedestrians, bicycles, and other non-motorized vehicles. Unlike the roadway programs, GHG reductions shown for these multi-use paths do not reflect improved traffic efficiency. Instead, construction of a multi-use path is assumed to make the non-motorized modes more attractive. The annual GHG reduction shown reflects an estimate of mode shifts away from auto across these seven projects.

While costs and cost-effectiveness will vary widely within these three investment programs, the relationships of the three program averages make sense intuitively. Much of the inefficiency of regional traffic is the result of obsolete and poorly functioning intersections. Investing in only those lane-miles required to undertake the intersection program would reduce the most amount of GHG for the least cost. At the opposite extreme are the investments in multi-use paths. Most of the user benefits accrue to existing bicyclists and pedestrians, and the GHG reductions shown here are achieved only by attracting incremental users abandoning the auto mode.

The effects of roadway improvement projects on GHG emissions vary widely. It is possible, however, to compare the cost-effectiveness of roadway and multi-use path projects. Project cost and cost-effectiveness averages for the four community types are intuitively reasonable, as are the ratios developed by type of investment program. Insofar as GHG reduction is a high priority, the most important variable identified in this analysis is the GHG reduction per lane-mile, which reflects the ability of a modern roadway design to improve travel efficiency.

5.3.2   Transit Improvements

As with roadway and multi-use projects, shuttle services can affect the success of other more cost-effective GHG strategies by balancing equity and other needs of the transportation system as a whole. They can offer other significant benefits including mobility, transportation equity, and livability. The service allows people who would ordinarily drive to their destination the option to leave their car at home and use public transportation.

In the past, the MPO funded start-up shuttle-bus services under the former Suburban Mobility or Clean Air and Mobility programs through the Congestion Mitigation and Air Quality program. The CMAQ program allows funding for capital vehicle procurement and as many as three years of operations assistance for shuttle services.

Staff reviewed seven services that were funded by the MPO for their GHG reductions and cost-effectiveness. The analyses included information that was submitted at the time the proponents requested funding. The MPO's policy was to fund as much as 80 percent of the service in its first year, with the proponent paying for the remaining 20 percent. The cost-effectiveness analysis was done for projected ridership in the first year of service. The seven shuttle services, although funded since 2007, are still in operation today. However, updated information about ridership was not obtained for this study. The seven projects are shown in Table 5.3.

TABLE 5.3
Projected Greenhouse Gas Reductions
from MPO-Funded Shuttle Services

Sponsor	Service	Total MPO Investment	Net CO_2 Tons/Year	Initial MPO Cost/Tons per Year
MetroWest	Route 7	$43,438	42	$1,042
MetroWest	Woodland Service	139,000	147	$947
Cape Ann Transportation Authority	Stage Fort	8,000	7	1,214
Acton	Dial-a-Ride	65,993	48	1,363
Acton	Park and Ride	52,993	94	561
GATRA	Franklin Service	175,655	30	5,852
GATRA	Marshfield/Duxbury Service	186,608	146	1,280
Combined		$671,687	514	$1,307

GATRA = Greater Attleboro-Taunton Regional Transit Authority.
Source: Central Transportation Planning Staff.

As shown in Table 5.3, the shuttle services for which the MPO provided start-up funding have a combined cost-effectiveness of $1,307 per ton of CO_2. Although updated ridership information for the services described above was not available, staff did have updated ridership information for shuttle services provided by the 128 Business Council Transportation Management Association (TMA). The 128 Business Council received a $50,000 grant under the former program for shuttle service to and from Alewife station in 1996. That proposal projected a daily VMT reduction of 1,400. The Council has expanded its services to Alewife Station and provides additional shuttles to Needham and Waltham. The current ridership for the additional service is approximately 4,500 daily riders with a corresponding CO_2 reduction of 323 tons per year. This is a good example of how an MPO investment can spark a successful service to reduce auto trips and GHG emissions.

Funding this type of service is the most cost-effective to the MPO in reducing CO_2 compared to the other three types of investments (Complete Streets, Intersections, and Bicycle/Pedestrian). This is because the sponsors continue supporting the services to realize mobility benefits that also result in significant GHG reductions.

5.3.3 GHG Reductions from Projects Statewide

MassDOT performed a GHG analysis for projects that were included in the 2013−2019 Statewide Transportation Improvement Programs grouped into similar investment programs as the investment programs used by the Boston Region MPO. The only difference was that MassDOT's calculations were done over the useful life of the project, while the MPO's analysis shows the reductions for the project's first year. The useful life for highway, bicycle, and pedestrian projects was 50 years and the useful life for transit projects was 15 years.

Table 5.4 compares statewide and MPO cost-effectiveness calculations with the projects in descending order from projects that are most cost-effective to those with a lower impact. The MPO information presented earlier in this section was revised to useful life as described above to show a comparison with the statewide results.

TABLE 5.4
Cost-Effectiveness of Statewide and MPO Investment Programs

Investment Program	Dollars of Investment (Tons per Year)	Dollars of Investment (Over the Useful Life)
MPO Shuttle Startups	$1,307	$87
MPO Intersections	7,000	140
MA. Bus Service Expansion and Bus Replacement	9,850	197
MPO Complete Streets	21,000	420
MPO Bicycle/Pedestrian	39,000	780
MA Traffic Operation improvements	43,200	864
MA Bicycle/Pedestrian	151,550	3,031

Source: Central Transportation Planning Staff.

As shown in the table, when comparing similar investment programs between the MPO and the state as a whole, the Boston Region MPO area has a lower cost per ton, which can be attributed to the higher density in the Boston region, and subsequent higher usage.

5.3.4 Other Projects that Reduce GHG Emissions

In addition to projects funded under the investment programs above, the MPO funded other projects under the former Suburban Mobility or Clean Air and Mobility programs. Many of these projects did not provide enough information to allow for a quantitative GHG analysis; however, they were deemed eligible to receive funding as part of CMAQ funding because they reduce pollutants as outlined in FHWA guidance.

A description of these projects funded by the MPO is provided below for reference purposes.

Transit Improvements

- MBTA procurement of new locomotives: Twenty new diesel electric locomotives replaced the older portion of the Commuter Rail locomotive fleet. The new locomotives produce 60 percent fewer emissions compared to locomotives in the MBTA's current fleet. The emissions savings for 20 locomotives is equivalent to taking approximately 1,077 cars off the road each day.

- MBTA procurement of switching locomotives: The MBTA switchers are stationed in rail yards to facilitate movement of rolling stock equipment— one in the north (Boston Engine Terminal) and one in the south district (Readville) of the MBTA's commuter rail system. The main function of the switchers is to move equipment throughout the yards. The MBTA purchased two new hybrid (battery pack with two small engines) switching locomotives and replaced the two older (vintage 1950s) diesel switching locomotives. The newer technology results in fewer GHG emissions.

Bicycle and Pedestrian Programs

- Boston Regional Bike Share (Hubway): The City of Boston launched its bike share system, Hubway, in August 2010 with a network of more than 50 stations, making more than 550 bicycles readily available to students, commuters, and visitors. The City of Cambridge joined the Hubway system with 14 stations, and the City of Brookline also added two stations.

  The Hubway system now provides more than 1,300 bikes at 140 stations throughout Boston, Brookline, Cambridge, and Somerville, and is continuing to add more stations. Funding from the MPO's Clean Air and Mobility Program for the City of Boston was $225,000, which funded portions of bike share expenses including warehousing, administration, information technology, and equipment maintenance. $100,000 funded expenses for supportive programs including education and safety campaigns, classes and public events, rack installation, and staffing. The City of Cambridge also applied for a Clean Air and Mobility Program grant for $228,384, which enabled Cambridge to participate in the regional Bike Share program. Brookline requested $98,308 to implement the program there.

- MBTA Bikes on Buses: The MBTA requested funding from the Clean Air and Mobility program to help meet its goal of making all buses bike accessible by 2012. The MBTA implemented a phased program of installing front-mounted bike racks on its buses. MPO funding was used to install bike racks on the remaining 310 MBTA buses so customers within the 46-community MBTA direct bus service area were assured that 100% of the MBTA vehicle bus fleet accommodated bikes. This program also will help with last mile connections.

Alternative Fuels and Vehicles

- Cambridge Clean Air Cab: This program provided an incentive to private taxicab owners to replace their existing, gas powered cabs with hybrid vehicles; it used funds provided through CMAQ to pay as much as $10,000 per vehicle to help cover the additional cost of purchasing a hybrid model vehicle.

Chapter 6—Ongoing Work and Next Steps

6.1   ONGOING WORK

In addition to the work being performed by MassDOT to identify potential new GHG emission calculation tools described above, in section 5.2, several other activities are underway at the state and MPO that will help the MPO to make decisions to fund the most cost-effective projects to reduce GHG emissions. Once completed, staff will update the MPO on outcomes of these activities, described below.

6.1.1   MPO Initiative

As discussed in section 5.1, the MPO adopted various transportation investment programs. One of the new programs is the Community Transportation/Parking/Clean Air and Mobility program. MPO staff is currently conducting a study on First-Mile and Last-Mile Transit Connections as part of the MPO's Unified Planning Work Program, as described in the next section.

First-Mile and Last-Mile Transit Connections Study

During the MPO's LRTP outreach in fall 2014, a frequent topic was ways to address first- and last-mile" connections to and from the region's transit system, particularly in suburban areas. People expressed interest in strengthening links, for example, by providing or increasing shuttle service (including expanding the frequency and hours of existing services) to link MBTA commuter rail stations and suburban communities. Because of this public interest, the MPO established a new investment program and allocated funding to a Community Transportation Investment Program. The MPO then allocated funding to a First-Mile and Last-Mile Transit Connections study to identify locations that could apply for funding allocated to this new program. This program will help reduce the number of vehicle-miles-traveled, and hence GHG emissions, by providing options to commuters and others to switch to transit rather than use their automobiles.

In this study, MPO staff would assist municipalities, Transportation Management Associations, or other service providers that requested planning support for addressing first- and last-mile connections to transit. The first phase of that study currently is underway. Candidate locations are being identified through outreach to MAPC subregions and other MPO outreach activities. For identified locations, MPO staff will document barriers and opportunities for linking residential, commercial, and employment areas to transit services and stations, and will propose services that could fill the gaps. Staff also may recommend improvements to support access for pedestrians and bicyclists, where applicable.

6.2   MassDOT Initiatives

The MPO recently adopted its LRTP, *Charting Progress to 2040*, without the benefits of a number of MassDOT initiatives. For that reason, the MPO chose not to allocate funding to major infrastructure projects in the last ten years of the LRTP planning horizon until information from ongoing activities was completed. A summary of these initiatives is provided below.

Focus40, MassDOT's Vision for MBTA's investments

MassDOT and the MBTA are in the process of developing a 25-year strategic vision for MBTA investments. This vision, Focus40, will be developed during the next year, and will engage the public as it drafts financially responsible, long-term investment strategy through 2040. It will update the MBTA's current Program for Mass Transportation (PMT). The MBTA's enabling legislation requires the Authority to update the PMT every five years and to implement the policies and priorities outlined in it through the annual Capital Investment Program (CIP).

The MPO felt it was important to have this information before determining the projects that could be funded by the MPO in later years of its planning horizon. Transit will help the MPO to achieve its Capacity Management and Mobility goal and will help in achieving its Clean Air and Clean Communities goal, specifically reducing GHG. As indicated in Chapter 4—Promising Strategies for Reducing GHG Emissions Identified in the Literature Review, transit investments could increase transit ridership and decrease the use of SOVs.

Focus40 will be developed in two phases:
1. Phase 1 will illustrate where the MBTA stands today regarding asset inventory, condition, and service performance. System-level reports will be developed for each mode of transit:
   - Buses
   - Rapid Transit
   - Commuter Rail
   - Paratransit
   - Ferry
   - Systemwide Improvements
2. Phase 2 will imagine the region that the MBTA should be planning for during the next 25 years.

Once these phases are completed, MassDOT and the MBTA will work with the public and stakeholders to develop and evaluate different investment strategies to address current and future needs.

MassDOT Capital Investment Plan

MassDOT and the MBTA are preparing five-year capital plans that will guide investments in the transportation system between 2017 and 2021. The Capital Investment Plan (CIP) will determine and prioritize investments for the next five years. It will cover all transportation projects—ranging from highway and municipal projects to regional airports, rail and transit, including the MBTA and Regional Transit Authorities, and bicycle and pedestrian projects.

Once the CIP is completed, the MPO will have information on projects and programs that the state will fund over the next five years. This will allow the MPO to consider projects that were not part of the CIP, which it may want to fund under the MPO target program to help move toward its objective of reducing GHG emissions.

6.2   NEXT STEPS

6.2.1 Implementing Strategies Outlined in the Literature Review

This report was undertaken to identify cost-effective GHG reduction strategies that can help inform MPO investment decisions. In the literature review, 23 strategies—required employer-offered compressed work week and compressed workweek: mandatory public and voluntary private are separated resulting in 24 strategies in Appendix A—were identified that fall into three categories:

- Creating a more efficient transportation system that has lower GHG emissions
- Promoting fuel efficiency and cleaner vehicles
- Coordinating transportation with land use decisions

Of these strategies, it was determined that the MPO could support 14 either through funding in the LRTP and TIP, study through the UPWP with eventual funding for implementation in the LRTP or TIP, and publicizing through public outreach. Table 6.1 shows the 23 strategies with the MPO fundable strategies in green. Strategies that the MPO could study that are not in green would require a partnership with another agency in order to implement that strategy. Also included in the table are rankings for potential GHG reductions and the average direct cost-effectiveness of strategies for which cost information was available. The rankings of the GHG and cost-effectiveness information are outlined in section 4.2 of the report.

TABLE 6.1
Twenty-Three Promising Strategies by Type,
Potential MPO Role in Implementation, and GHG
and Cost-Effectiveness Ranking
(Based on National Data)

Category	Strategy	Strategy Type	Potential MPO Role	GHG Ranking*	Cost Ranking**
Creating a More Efficient Transportation System that Has Lower GHG Emissions	Pedestrian Improvements	Transportation System Planning, Funding, and Design	Fund or Study	14	13
	Bicycling Improvements	Transportation System Planning, Funding, and Design	Fund or Study	19	12
	Workplace Transportation Demand Management	Travel Demand Management	Fund or Study	13	9
	Teleworking	Travel Demand Management	Fund or Study	11	17
	Individualized Marketing of Transportation Services	Travel Demand Management	Fund	17	8
	Ridesharing	Travel Demand Management	Fund or Study	24	7
	Car Sharing	Travel Demand Management	Fund or Study	23	4
	Compressed Work Weeks	Travel Demand Management	Study	5/15	1
	Expansion of Urban Fixed-Guideway Transit	Transportation System Planning, Funding, and Design	Fund or Study	10	18
	Rail Freight Infrastructure	Transportation System Planning, Funding, and Design	Fund or Study	21	11
	Increased Transit Service	Transportation System Management and Operations	Fund or Study	12	19
	Transit Fare Reductions	Transportation System Management and Operations	Study	16	16

Category	Strategy	Strategy Type	Potential MPO Role	GHG Ranking*	Cost Ranking**
	Pay-As-You-Drive Insurance	Taxation and Pricing	Study or Advocate	3	6
	Vehicle-Miles-Traveled Fees	Taxation and Pricing	Study or Advocate	6	10
	Congestion Pricing	Taxation and Pricing	Study or Advocate	8	14
	Carbon Tax or Cap-and-Trade	Taxation and Pricing	Study or Advocate	1	NA
	Alternative Construction Materials	Construction Practices	Advocate	9	15
Promote Fuel Efficiency and Cleaner Vehicles	Truck-Idling Reduction	Transportation System Management and Operations	Fund or Study	18	5
	Reduced Speed Limits	Transportation System Management and Operations	Study or Advocate	7	3
	Driver Education and Eco-Driving	Public Education	Publicize	2	N/A
	Information on Vehicle Purchases	Public Education	Publicize	20	N/A
Coordinate Transportation with Land Use Decisions	Compact Development	Land Use Policies	Study or Advocate	4	2
	Parking Management	Land Use Policies	Fund or Study	22	NA

* GHG Ranking is from the most effective to least effective in reducing GHG emissions

**Cost Ranking is from the most cost-effective to the least cost-effective in reducing GHG emissions

Note: Green text indicates that a strategy can be funded by the MPO.

Source: Central Transportation Planning Staff.

As shown in the table, each category is broken down into strategy type:

1. Creating a more efficient transportation system that has lower emissions
   - Transportation System Planning, Funding, and Design
   - Transportation System Management and Operations Travel Demand Management
   - Taxation and Pricing
   - Construction Practices

2. Promoting fuel efficiency and cleaner vehicles
    - Transportation System Management and Operations
    - Public Education
3. Coordinating transportation with land use decisions
    - Land Use Policies

The majority of the strategies fall into "*creating a more efficient transportation system*" category. The pricing strategies, such as cap-and-trade or carbon tax, congestion pricing, pay-as-you-drive insurance, and VMT fees, have the most potential to reduce GHG emissions. The MPO does not have the authority to implement these programs. Thus, for these strategies, it may be appropriate to advocate for implementation to whichever local, State, or Federal body that has jurisdiction. For example, a carbon tax or cap-and-trade policy could greatly benefit greenhouse gas reduction in transportation, but would fall under national or state jurisdiction. The MPO could, however, study or advocate for the programs.

The MPO can implement a number of other strategies in this category. Infrastructure investments in transit, walking, bicycling, and rail facilities and improvements to transit service (transportation system planning, funding, and design and transportation system management and operations) are needed to strengthen low-carbon transportation choices; however, they are at the mid-to-lower end of strategies that are both GHG and cost-effective. Many of the travel demand management strategies that the MPO could fund rank lower in GHG reduction, but many are more cost-effective than the infrastructure projects. Both the infrastructure and the travel demand management strategies should not be discounted in importance because of their smaller relative potential for reductions or lower cost-effectiveness. These strategies can affect the success of others, or are important for balancing equity and other needs of the transportation system as a whole. Some of the least-cost effective strategies, namely the transit-focused strategies and teleworking, have the ability to achieve larger reductions in total; without these strategies, larger emission reductions might not be achieved. In addition, both the transit strategies and teleworking have many other benefits that support cost expenditure, in addition to GHG reduction. These strategies have important mobility and accessibility benefits.

The MPO can publicize two of the strategies that fall under the "*promoting fuel efficiency and cleaner vehicles*" category. Driver education/eco-driving can play a big part in reducing greenhouse gas emissions from transportation; however, the MPO can only publicize and promote this program for its GHG benefits. The MPO could consider seeking funding partnerships to deploy driver education or eco-driving. It also can study truck-idling reduction and potentially fund the

purchase of idle reduction equipment for trucks through its CMAQ program. The MPO could study the effects of implementing reduced speed limits, but this strategy would ultimately need to be enforced through the local and state police.

All strategies, in the "*coordinating transportation with land use decisions*" category, will require partnerships or strengthened collaboration across agencies. For instance, MAPC develops the land use plan for the region, so it is better positioned to support the compact land use strategy. Ultimately, local entities would need to implement any land use changes in their municipalities. Compact development not only has the potential to achieve the fourth-largest GHG reductions, but also could affect the strategies that the MPO can directly implement—transit infrastructure and improvements and walking and bicycle facilities. This strategy highlights the benefits of the MPO/MAPC partnership.

Partnering may be advantageous for strategies that the MPO can study. For example, MAPC has already worked with communities in the Boston region to improve parking management. The MPO may be able to use its transportation expertise to support its existing work further by coordinating with MAPC to study promising parking policies under consideration so they can be implemented by municipalities.

Another example, the workplace transportation demand management and outreach campaigns and incentives strategies could benefit and expand from the existing work of MassRIDES and transportation management associations. The MPO's new Community Transportation program can help to provide CMAQ funding for startup shuttle-service operations.

Deployment of some of the greenhouse gas reduction strategies discussed in the literature review would represent change in the MPO's historical funding patterns. The MPO may consider forging new partnerships for implementation or funding of strategies. As noted in the literature review, all the strategies could benefit from further research. Data about which strategies Massachusetts is implementing could make for better-informed decision making. Further research is needed to quantify the potential emissions reductions at the state and metropolitan regional levels.

6.2.2 Current MPO Investments

Also as part of the report, staff analyzed projects that were funded or proposed for funding in past Transportation Improvement Programs to determine their GHG cost effectiveness. The analyses included projects under four MPO investment programs:

1. Complete Streets
2. Intersection Improvements
3. Bicycle and Pedestrian Multi-Use Paths
4. Shuttle Bus Services

The current LRTP includes funding for these programs beginning in 2021 through 2040. The GHG analysis for this study and the literature review show that bicycle and pedestrian paths and bicycle and pedestrian improvements as part of Complete Streets projects are ranked low for GHG reductions. However, they can affect the success of others strategies, or are important for balancing equity and other needs of the transportation system as a whole:

- Safety – Bike lanes and protected bike lanes in particular are associated with many safety advantages, not only for people biking but also for people walking.
- Capacity management and mobility goal – by increasing the percentage of population and places of employment with access to these facilities and encourages a modal shift away from driving, decreasing VMT and therefore GHG emissions.
- Economic Vitality – These modes offer substantial vehicle cost savings; when the costs of implementation are considered together with vehicle cost saving for users supporting the economic vitality goal.
- Health – Bicycle and pedestrian facility improvements also generate benefits in terms of increased physical activity and improved public health.
- Land Use – Bicycle and pedestrian improvements, like transit, benefit compact development. These non-motorized modes support transit use by making connections to and from transit stops, and, like transit, are "much more effective" where destinations are close together in densely developed areas.

Shuttle services were not addressed in the literature review, however analysis done for this report shows that they are the most cost-effective of the four MPO investment programs for reducing GHG emissions. The MPO adopted a new funding program—Community Transportation, Parking and Clean Air and Mobility—to begin in 2021. The MPO should monitor the success of this program to ensure that enough funding is provided to promote this program for its GHG reduction potential, among other potential capacity management and mobility and economic vitality benefits.

Intersection improvements are the second most cost-effective of the MPO strategies. The analysis shows that they are projected to have a GHG reduction with an average of 542 tons per lane-mile per year. However, as outlined in the Literature Review, it should be cautioned that traffic management improvements such as intersection improvements is a strategy that reflects lower GHG emissions savings after induced demand is taken into account.