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TRANSIT COOPERATIVE RESEARCH PROGRAM

TCRP RESEARCH REPORT 226

An Update on Public Transportation's Impacts on Greenhouse Gas Emissions

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Public Transportation • Environment

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2021

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TRANSIT COOPERATIVE RESEARCH PROGRAM

The nation's growth and the need to meet mobility, environmental, and energy objectives place demands on public transit systems. Current systems, some of which are old and in need of upgrading, must expand service area, increase service frequency, and improve efficiency to serve these demands. Research is necessary to solve operating problems, adapt appropriate new technologies from other industries, and introduce innovations into the transit industry. The Transit Cooperative Research Program (TCRP) serves as one of the principal means by which the transit industry can develop innovative near-term solutions to meet demands placed on it.

The need for TCRP was originally identified in *TRB Special Report 213—Research for Public Transit: New Directions,* published in 1987 and based on a study sponsored by the Urban Mass Transportation Administration—now the Federal Transit Administration (FTA). A report by the American Public Transportation Association (APTA), *Transportation 2000,* also recognized the need for local, problem-solving research. TCRP, modeled after the successful National Cooperative Highway Research Program (NCHRP), undertakes research and other technical activities in response to the needs of transit service providers. The scope of TCRP includes various transit research fields including planning, service configuration, equipment, facilities, operations, human resources, maintenance, policy, and administrative practices.

TCRP was established under FTA sponsorship in July 1992. Proposed by the U.S. Department of Transportation, TCRP was authorized as part of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). On May 13, 1992, a memorandum agreement outlining TCRP operating procedures was executed by the three cooperating organizations: FTA; the National Academies of Sciences, Engineering, and Medicine, acting through the Transportation Research Board (TRB); and the Transit Development Corporation, Inc. (TDC), a nonprofit educational and research organization established by APTA. TDC is responsible for forming the independent governing board, designated as the TCRP Oversight and Project Selection (TOPS) Commission.

Research problem statements for TCRP are solicited periodically but may be submitted to TRB by anyone at any time. It is the responsibility of the TOPS Commission to formulate the research program by identifying the highest priority projects. As part of the evaluation, the TOPS Commission defines funding levels and expected products.

Once selected, each project is assigned to an expert panel appointed by TRB. The panels prepare project statements (requests for proposals), select contractors, and provide technical guidance and counsel throughout the life of the project. The process for developing research problem statements and selecting research agencies has been used by TRB in managing cooperative research programs since 1962. As in other TRB activities, TCRP project panels serve voluntarily without compensation.

Because research cannot have the desired effect if products fail to reach the intended audience, special emphasis is placed on disseminating TCRP results to the intended users of the research: transit agencies, service providers, and suppliers. TRB provides a series of research reports, syntheses of transit practice, and other supporting material developed by TCRP research. APTA will arrange for workshops, training aids, field visits, and other activities to ensure that results are implemented by urban and rural transit industry practitioners.

TCRP provides a forum where transit agencies can cooperatively address common operational problems. TCRP results support and complement other ongoing transit research and training programs.

TCRP RESEARCH REPORT 226

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The project team would like to thank our interview participants for their time and insights: Sean Donaghy, Manager of Energy Programs, Massachusetts Bay Transportation Authority (MBTA); Projjal Dutta, Director of Sustainability Initiatives, New York Metropolitan Transportation Authority (MTA); Angie Gompert, Administrator, Martha's Vineyard Transit Authority (VTA); Sarah Ingle, Manager of Long Range Planning, Rhode Island Public Transit Authority (RIPTA); John Lancaster, Director of Planning & Scheduling, Memphis Area Transit Authority; and Amit Price Patel, Principal, SITELAB Urban Studio. We would also like to thank the TCRP project panel members for their guidance and contributions.

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FOREWORD

By Dianne S. Schwager
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TCRP Research Report 226: An Update on Public Transportation's Impacts on Greenhouse Gas Emissions updates aspects of previous TCRP research on public transportation's role in reducing greenhouse gas (GHG) emissions and supporting sustainability. This report provides useful information that is presented in clear, easy-to-understand language amply supported by exhibits and graphics. The report will be of immediate use to local, regional, state, and national organizations concerned with public transportation, air quality, energy, sustainability, and climate change mitigation. Communities planning low-carbon transportation solutions will find estimates of the GHG emissions of their local transit systems, as well as information on the GHG impacts of fuels, technologies, and ridership changes. The supporting deliverables give transit agencies planning and communication tools, including ready-to-use graphics and data showing the reduced carbon footprint of an individual taking transit and transit agency contributions to GHG reduction and sustainability.

As communities work to address climate change by reducing GHG emissions and becoming more resilient, many are looking to public transportation as a climate action strategy. This report provides updated analysis to transit's previously known importance as a climate solution with a national assessment of public transportation's GHG impacts in 2018. Public transportation in the United States saved 63 million metric tons of carbon dioxide equivalent (MMT CO_2e) emissions in 2018—the equivalent of taking 16 coal power plants offline for a year.

Public transportation's impacts on GHG emissions include (1) transit vehicle GHG emissions: the GHG emissions associated with transit vehicle fuel use; (2) transportation efficiency GHG savings: the GHG emissions saved by passengers riding transit rather than using personal vehicles; and (3) land use efficiency GHG savings: the GHG emissions saved by the broader impact of transit on vehicle miles traveled in the community. A scenario analysis to 2030 and 2050 shows the potential for public transportation to increase its GHG benefits into the future.

In addition to *TCRP Research Report 226,* this research project produced the following deliverables, which can be found by searching for "*TCRP Research Report 226*" at www.TRB.org:

1. **Factsheets.** Three one-page factsheets that present key findings regarding transit as a climate solution.
2. **A PowerPoint** slide deck for transit agencies to add their own data for climate communications.
3. **A simple spreadsheet tool** that provides this study's 2018 GHG impact findings by transit agency and allows users to apply several of the future scenarios to see how their transit agency's GHG impacts change with electrification, clean power, and ridership increases.

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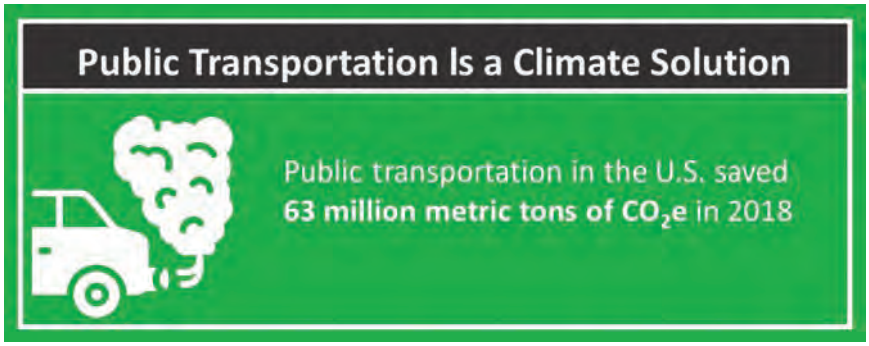
SUMMARY

An Update on Public Transportation's Impacts on Greenhouse Gas Emissions

Transportation is a major source of the greenhouse gas (GHG) emissions that are causing climate change (U.S. EPA 2020d). As communities work to cut emissions and become more resilient, they are looking to public transportation as a climate action strategy. This report provides updated national analysis of public transportation's role as a climate solution by documenting public transportation's 2018 GHG impacts.

Public Transportation's GHG Emissions Impacts



Public transportation in the United States saved 63 million metric tons of carbon dioxide equivalent (MMT CO_2e) emissions in 2018—the equivalent of taking 16 coal power plants offline for a year (U.S. EPA 2020c). This study examined public transportation's impacts on GHG emissions by calculating the difference between transit vehicle GHG emissions (12 MMT of CO_2e) and GHG reductions associated with transit (Figure 1).

- **Transportation Efficiency GHG Savings:** The GHG emissions saved by passengers riding transit rather than using personal vehicles: **9 MMT CO_2e** in 2018. Transit passenger surveys show 33% of transit passenger miles would otherwise be replaced by personal vehicle miles (APTA 2020).
- **Land Use Efficiency GHG Savings:** The GHG emissions saved by the broader impact of transit on vehicle miles traveled (VMT) in the community: **66 MMT CO_2e** in 2018. Even residents who do not ride transit themselves save GHGs because transit creates land use efficiencies, such as through shorter driving trips, fewer driving trips, and more trips on foot or by bicycle.
- **Net Impact:** 12 MMT CO_2e emitted – 75 MMT CO_2e reduced = 63 MMT CO_2e.

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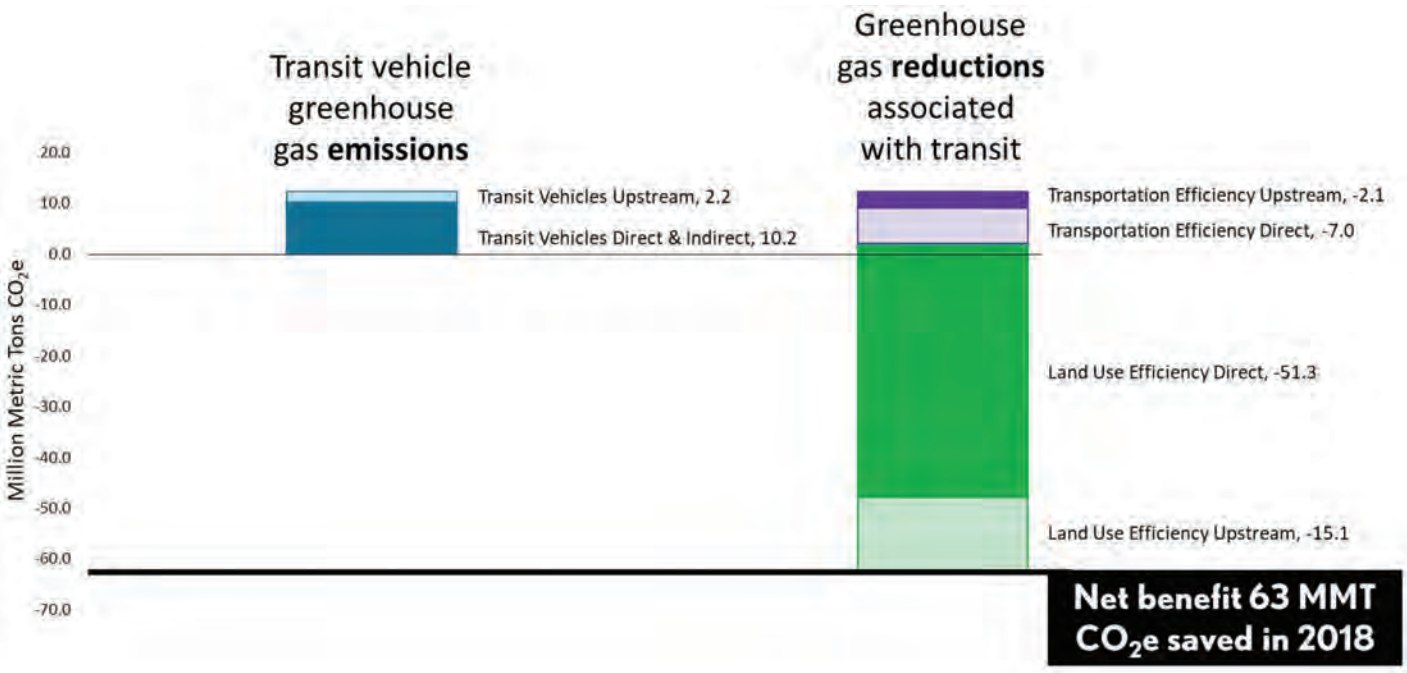

Figure 1. GHG impacts of public transportation in 2018.

This study takes into account the full life cycle of transportation fuels (see Figure 1), as follows:

- **Direct** CO_2e emissions at the vehicle.
- **Indirect** CO_2e emissions from power plants and hydrogen production facilities.
- **Upstream** CO_2e from fuel production and distribution.

Public Transportation's VMT and Fuel Impacts

Communities with public transportation avoided 148 billion miles of personal vehicle travel in 2018 through transportation efficiency and land use efficiency savings, or 5% of the 3 trillion total U.S. vehicle miles that year (FHWA 2019a). Transit vehicles traveled 4.7 billion miles in 2018, and the average transit vehicle had 12 passengers (FTA 2020a).

Public transportation helped avoid 6.6 billion gallons of gasoline use in 2018 through transportation efficiency and land use efficiency savings, and transit vehicles used significantly less energy than that—837 million gallons of fossil fuels, 49 million gallons of biodiesel and ethanol, and 6.7 billion kilowatt hours (kWh) of electricity (FTA 2020a).

Public Transportation's Individual Impacts

Public transportation helps passengers reduce their carbon footprint. An individual riding transit in 2018 contributed 55% fewer GHGs per mile than would have been done through driving or ridehailing alone (0.23 kg CO_2e per transit passenger mile versus 0.51 kg CO_2e per mile for a single-occupancy private vehicle). Even at a U.S. average automobile occupancy of 1.67 passengers per trip, the GHG emissions of personal vehicle travel were higher than the transit average on a per-passenger-mile basis (0.23 kg CO_2e per transit passenger mile versus 0.30 kg CO_2e per mile for an average occupancy private vehicle).

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The most carbon-efficient transit mode on a per-passenger-mile basis was rail-based transit, which transported 60% of passenger miles in 2018. Buses varied in emissions efficiency depending on fuel, technology, operations, and occupancy. Electric and biodiesel buses had the lowest GHG emissions per passenger mile in 2018. Passengers on ferries and vans had higher emissions profiles, but those modes only accounted for 5% of passenger travel.

Transit Agency Contributions to GHG Emission Reduction and Sustainability

Transit agencies are increasingly taking climate actions. Transit GHG emissions have fallen over the past 15 years on both an overall basis and a per-passenger-mile basis. Even those agencies that are not setting specific GHG targets are pursuing fuel efficiency and cost savings that can bring GHG savings. Transit agencies are adopting lower-carbon vehicle technologies and fuels, such as hybrids, regenerative braking, biofuels, and electric vehicles. The growth of electric buses in recent years has been notable and especially beneficial as the use of more carbon-intensive grid electric power sources like coal has lessened while solar and wind have grown.

A continuation of these trends will enable transit to be a low-carbon solution to meeting transportation needs into the future. This will be even more true if ridership and occupancy increase over time. However, decreases in ridership, whether due to COVID-19 creating lasting disruptions in our travel patterns or scaling back of transit service, will shrink transit's climate benefits. A scenario of potential transit GHG savings to 2030 and 2050 was developed to show how transit climate action can grow impacts.

That said, GHGs are not the only metric by which transit success should be judged. In addition to benefiting the climate, transit provides essential mobility and access to communities that are otherwise made vulnerable by age, income, disability, neighborhood disinvestment, or other forces that may also put them on the front lines of climate disruption. Planning for a sustainable, resilient future must include public transportation that serves community needs.

Research Approach

The emissions calculations in this analysis are based on data for transit vehicles, energy use, and passengers reported in the National Transit Database (NTD) of the FTA (FTA 2020a). The GHG calculation methods follow best practices from the American Public Transportation Association (APTA 2018), the U.S. Environmental Protection Agency (U.S. EPA 2020d), and the GHG Protocol [World Business Council for Sustainable Development (WBCSD) and World Resources Institute (WRI) 2004], as documented in Chapter 2 and the appendices of this report. The land use efficiency GHG savings were modeled using household travel survey data from 28 regions using a structural equation model documented in the methodology.

The emissions values in this report include direct, indirect, and upstream GHG emissions associated with vehicle travel.

- **Direct GHG Emissions** are the carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) emissions that occurred at the vehicle when fuel was consumed.
- **Indirect GHG Emissions** occurred at the power plant when electricity was produced or in the process of producing hydrogen.

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- **Upstream Emissions**, sometimes referred to as "well-to-pump" emissions, are the GHG emissions that occurred during fuel production and distribution.

Thus, the emissions values presented here are "well-to-wheels" values or the full life-cycle GHG emissions associated with using a fuel.

In 2018, public transportation in the United States used 49 million gallons of biodiesel fuel and 47,000 gallons of ethanol. The CO_2 emitted by these fuels is considered "biogenic" by major GHG accounting standards because it is sourced from plant matter and part of the natural carbon cycle. In 2018, transit use of biodiesel and ethanol emitted 0.5 MMT biogenic CO_2.

The emissions calculations presented here do not include the GHG impacts of transit operations, which may represent 5% to 35% of transit agency GHG emissions (McGraw et al. 2010, Southworth et al. 2011). This is an area worthy of further research.

Transit agencies report their activity data to the NTD each year, so the GHG calculations in this report could be repeated annually as part of the database compilation process, which would provide transit agencies and communities necessary data to manage climate impacts.

Project Resources

The GHG analysis presented here is meant to be a resource for transit agencies, decision makers, communities, and other public transportation and sustainability stakeholders. This information can be used to guide decision making toward lower-carbon fuels, technologies, and operations improvements as well as demonstrating the importance of transit ridership and occupancy as a climate solution. The analysis in this research project is also meant to provide the information necessary to communicate public transportation's important role as a climate solution. To those ends, tools for communication and ideation have been created as part of this project. These supplementary materials can be obtained by going to www.TRB.org and searching for "*TCRP Research Report 226*":

1. **Three one-page factsheets** that present key findings regarding transit as a climate solution.
2. **A PowerPoint slide deck** summarizing these findings and the research they are based on with the infographics and charts used in this document and a template for transit agencies to add their own data for climate communications.
3. **A simple spreadsheet tool** that provides this study's 2018 GHG impact findings by transit agency and allows users to apply several of the future scenarios to see how their transit agency's GHG impacts change with electrification, clean power, and ridership increases.

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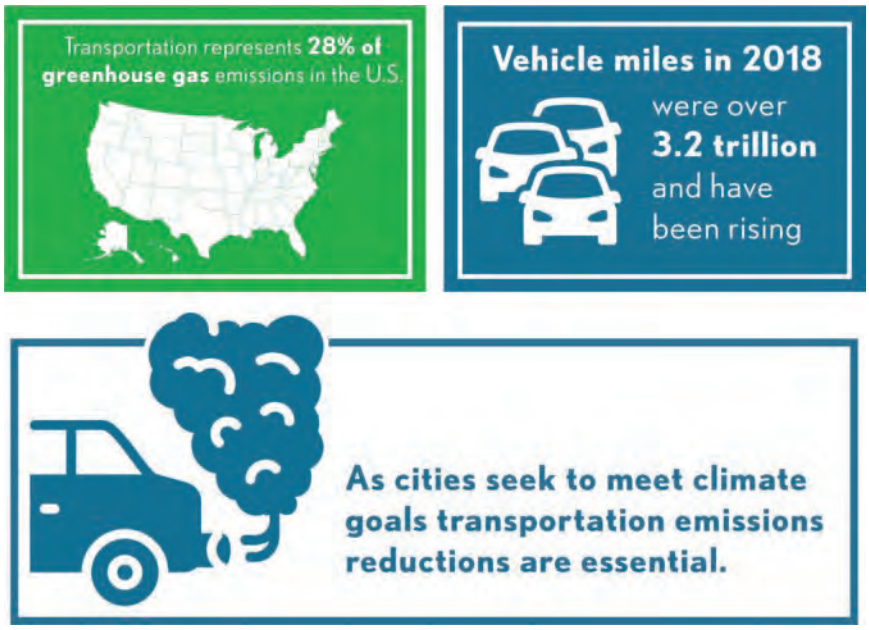
CHAPTER 1

Public Transportation's Greenhouse Gas Impacts in Context

Transportation is a major source of the greenhouse gas (GHG) emissions that are causing climate change. In 2018, transportation accounted for 28% of all GHG emissions in the United States, and 3.2 trillion vehicle miles were traveled on U.S. roads (U.S. EPA 2020d, FHWA 2019a). Global climate change is inflicting significant harm to communities through extreme storms, flooding, wildfires, heat emergencies, and more impacts to local economies, public health, and safety (U.S. Global Change Research Program 2018).

As U.S. communities work to cut emissions and become more resilient, they are looking to public transportation as a climate action strategy. For example, a 2020 Carbon Disclosure Project (CDP) and ICLEI–Local Governments for Sustainability survey of city climate change mitigation actions reported data on 43 U.S. cities taking 237 mass-transit–related actions (CDP and ICLEI 2020).



This report provides updated national analysis of public transportation's role as a climate solution by documenting its GHG impacts in 2018, the most recent complete data year available at the time of the analysis. (Data from 2019 released as this report went to publication indicate a similar level of transit vehicle and passenger activity.)

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Public Transportation's GHG Reduction Actions

Technology, Fuels, and Operations

TCRP publications such as *TCRP Synthesis 130: Battery Electric Buses—State of the Practice* provide a catalog of information for transit agency efficiency, energy savings, and emissions reductions (Hanlin et al. 2018). Practitioners have identified interest and investments in electrification, such as battery electric buses powered by renewable electricity, but cost and applicability are also driving interest in other technologies, such as compressed natural gas and hydrogen fuel cells (The Connecticut Academy of Science and Engineering 2018). However, interest in particular fuels may be shifting as more is learned about their full life-cycle GHG impacts. Installation of renewables on transit agency property, including solar canopies on parking lots, is another way that some transit agencies are taking climate action. There is interest in pairing that with energy storage to take fuller advantage of renewables and their GHG reduction potential. Some transit agencies are also procuring renewable grid-connected electricity.

Ridership and Land Use

Increasing ridership and increasing the occupancy per vehicle are other strategies that can lead to measurable emissions impacts. Transit agencies are working to optimize their routes and service to support additional ridership as travel needs evolve. *TCRP Research Report 221: Redesigning Transit Networks for the New Mobility Future* (Byala et al. 2021) provides case studies and toolkits for this purpose.

Several transit agencies are working with housing developers to encourage new housing near transit, an approach that can boost ridership and lower emissions [San Francisco Municipal Transportation Agency (SFMTA) n.d.]. There is a growing focus on affordable housing in response to rising costs around the country, and transit agencies are looking to create equitable transit-oriented development (TOD) to encourage land use densities without displacement [Bay Area Rapid Transit (BART) 2016]. Transit agencies are also interested in TOD beyond housing to a broader set of mixed land uses, including retail and job centers. State and local policy changes are enabling, and even in some cases requiring, zoning changes and TOD near transit stations. How passengers access transit is another point of focus, with transit agencies and communities improving bicycle and pedestrian access to stations and stops, which can also lower transportation emissions.

Overall, the literature shows that transit creates a net GHG emissions benefit for communities and that communities are looking to transit to help them meet their climate action goals. Transit agencies are meeting this demand with innovative strategies to reduce their own carbon footprints while increasing the emissions reductions benefits they bring to communities. This report seeks to clearly document these GHG impacts to help transit agencies plan and communicate with stakeholders about their contributions to climate action.

GHG Accounting Tools and Methods

APTA's 2018 *Recommended Practices for Quantifying Greenhouse Gas Emissions from Transit* is an update of its 2009 document that lays out GHG accounting methods for transit agencies. The APTA Recommended Practice has served as an important reference for the field, setting a framework for understanding the many emissions impacts of transit and providing practical approaches to assessment (APTA 2018). The APTA Recommended Practice references the Climate Registry General Reporting Protocol [The Climate Registry (TCR) 2019] and the GHG

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An Update on Public Transportation's Impacts on Greenhouse Gas Emissions

Protocol [World Business Council for Sustainable Development (WBCSD) and World Resources Institute (WRI) 2004] and their associated guidance documents in its recommendations, and those have been good resources for transit agencies as well. This study uses the APTA Recommended Practice as its analytical framework. The methods used to assess the GHG emissions impacts in these categories are further described in Chapter 2 and the appendices.

Publicly Available Tools to Estimate Transit GHGs

For transit agencies documenting their own emissions impacts or wanting to estimate the emissions of a specific transit project, several tools are publicly available, including U.S. EPA tools. Also:

- The FTA's 2017 *Greenhouse Gas Emissions from Transit Projects: Programmatic Assessment* and the "Transit Greenhouse Gas Emissions Estimator" spreadsheet tool provide useful data on the construction, operations, and maintenance of public transit systems (FTA 2016 and FTA 2017).
- The GHG Protocol's tools that, though not designed specifically for transit agencies, are widely used by organizations and communities in the United States to calculate emissions (WBCSD and WRI 2004).
- The spreadsheet tool released in conjunction with this report provides the GHG analysis findings by transit agency and mode along with simple electrification, clean energy, and ridership increase scenarios.

Previous Assessments of Public Transportation GHG Impacts

An estimation of U.S. public transportation's 2005 GHG impacts found a net 7 million metric tons of CO_2 (MMT CO_2) saved by public transportation through avoided personal vehicle use and congestion relief (Davis and Hale 2007). A follow-on study examined the vehicle miles avoided by non-transit riders in communities with transit, which increased transit's estimated net benefit to 37 MMT CO_2 (Bailey et al. 2008).

Calculating transit's GHG impacts is a well-established practice that continues to evolve as research provides new approaches and applied work creates the need for new information. This study seeks to update the understanding of transit GHG impacts and account for the changes that have occurred since the study of 2005 emissions.

Factors Changing Public Transportation's GHG Impacts

In the years since transit's 2005 GHG emissions were documented, major transit expansions have occurred in several cities. The National Transit Database (NTD) shows more than 1,000 miles of additional fixed guideway rail between 2009 and 2018 (FTA 2019a). Transit agencies also have many new ways to lower their emissions, such as through vehicle efficiency and alternative fuels (McGraw et al. 2010, Gallivan and Grant 2010, Hanlin et al. 2018).

There are many drivers of climate actions by transit agencies. National, state, and local policies have led to transit adopting new vehicles and fuels. Transit agencies have set their own internal goals for climate action. Transit agency partners, such as the communities and the institutions they serve, including universities, have set climate goals that further support transit decarbonization. Additionally, our understanding of transit's impacts in the community has grown. These are all factors that would lead one to believe that transit's GHG benefits were larger in 2018 than they were estimated to be in 2005.

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Even transit agencies without a specific climate target may be improving their fuel economy to reduce costs. Many service and operations improvements that transit agencies undertake to reduce costs or improve reliability also generate carbon savings, such as asset maintenance that keeps vehicle operating at maximum efficiency and transit traffic prioritization that reduces idling.

That said, there are counteracting factors that may be influencing transit GHG impacts as well—the rise of ridehailing services, relatively inexpensive gasoline, perception of public health risk, and transit service challenges, such as congestion delays, are among the factors that have affected transit ridership (Watkins et al. 2020, TransitCenter 2019). Nevertheless, as the assessment results in Chapter 3 demonstrate, public transportation's GHG benefit has grown significantly since 2005, and public transportation has the potential to provide even greater climate benefits going forward.

Public Transportation Emissions in the COVID-19 Era

The impact of the COVID-19 pandemic on public transportation has been significant but has not yet been fully documented in the literature, and the long-term impact remains to be seen. This study uses 2018 data, which is prior to any COVID-19 impacts, but there are some initial data points available that show the scale of change in 2020.

Many places began to institute regulatory policies that led to working from home and other travel activity changes in March 2020. Monthly data for 2020 show 3.1 billion transit passenger trips from March through December, as compared to 8.4 billion in the same period of 2019; however, not all transit agencies had reported their data for 2020 at the time of this writing (FTA 2020b).

The emissions impacts of this are likely complex, as all of the elements of public transportation's GHG profile are affected—less fuel will have been used to power transit vehicles in areas that have reduced service, but on some routes carrying essential workers, service has increased to address overcrowding concerns, and each transit vehicle is carrying fewer passengers on average. At the same time, the travel patterns of entire communities have been upended. It is hoped that the analysis of public transportation's climate impacts in 2018 provided in this report will give decision makers and stakeholders useful data to support transit's role as a climate solution in a post-pandemic future.

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CHAPTER 2

Research Approach

The modeling for this project focused on producing clear, well-documented results related to the climate and sustainability impacts of transit, and in particular:

- The national sustainability benefits associated with transit ridership,
- The reduced carbon footprint of individuals using public transit,
- Transit agency contributions to GHG emission reduction and sustainability, and
- Public transit's national and regional impact on GHG emissions and energy use related to land use and travel behavior.

The approach was to document the impacts of transit today based on existing data and research. The most recent complete data at the time of analysis was for 2018, so the findings are for that year.

The emissions calculations in this analysis are based on transit vehicle, energy use, and passenger data reported in the NTD (FTA 2020a). The GHG calculation methods follow best practices from the American Public Transportation Association (APTA 2018), the U.S. Environmental Protection Agency (U.S. EPA 2020d), and the GHG Protocol (WBCSD and WRI 2004), as documented in the methodology descriptions in this chapter and Appendix A. The land use efficiency GHG savings were modeled using household travel survey data from 28 regions using a structural equation model documented in this methodology and Appendix B.

Included Emissions. The emissions values in this report include direct, indirect, and upstream GHG emissions associated with vehicle travel. Direct GHGs are the carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) emissions that occurred at the vehicle when fuel was consumed. Indirect GHG emissions occurred at the power plant when electricity was produced or in the process of producing hydrogen. Upstream emissions, sometimes referred to as "well-to-pump" emissions, are the GHG emissions that occurred during fuel production and distribution. Thus, the emissions values presented here are "well-to-wheels" values or the full life-cycle GHG emissions associated with using a fuel. The calculated GHG values were multiplied by their 100-year global warming potentials (GWPs) and summed to be presented as carbon dioxide equivalents (CO_2e).

Excluded Emissions. The emissions calculations presented here do not include the GHG impacts of transit operations, such as electricity use at stations or offices, non-transit vehicles, infrastructure, and staff commutes, nor do these calculations include the life-cycle GHG impacts of transit vehicle production, maintenance, and disposal. The impact of fugitive emissions [such as sulfur hexafluoride (SF_6), hydrofluorocarbons (HFCs), and perfluorocarbons (PFCs)] were also not modeled due to a lack of transit-specific data on these emissions sources.

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An Update on Public Transportation's Impacts on Greenhouse Gas Emissions

A transit agency calculating its greenhouse gas inventory will include energy use in offices, stations, and non-transit vehicles, but that is not typically a large source of its emissions impact relative to transit vehicle operations (Chester and Horvath 2007). An examination of five past GHG inventories of transit agencies found that revenue transit vehicles represented 65% to 95% of transit agency GHG emissions (McGraw et al. 2010, Southworth et al. 2011).

Many transit agencies are examining these impacts in GHG inventories and reducing these emissions through energy efficiency and other improvements. Because there was not a national source for these data, they were left out of the analysis, but it is an area worthy of future research.

Research Approach

The direct, indirect, and upstream GHG emission impacts of public transportation are analyzed in three categories:

- **Transit Vehicle GHG Emissions**, which are the GHGs that result from the use of fossil fuels, hydrogen, and electricity to propel buses, trains, and other transit vehicles;
- **Transportation Efficiency GHG Savings**, which are the avoided personal vehicle emissions of transit passengers; and
- **Land Use Efficiency GHG Savings**, which are generated as communities with transit enable residents to drive less.

Calculating Emissions from Transit Vehicle Activity

The primary calculation method was that used in GHG accounting in communities around the world: given an activity of *x* at emissions rate *y*, what are the GHG emissions of that activity? (For example, the energy use of diesel buses and the CO_2 emission factor per gallon of diesel fuel.) Each transit agency's service vehicle emissions were calculated separately by mode type and fuel. The calculations are described further in Appendix A.

Vehicle Typology

The NTD provides transit data by mode names and vehicle types. For the purposes of this study, these have summarized into six mode types: bus, commuter rail, ferry, heavy rail, light rail, and van (see Appendix A).

Activity Data

The activity data used to calculate emissions from transit revenue vehicles are the energy use data and vehicle mileage data reported in the NTD. Many smaller transit agencies do not report fuel use to the NTD. Where vehicle mileage data were available, fuel use was estimated based on average fuel efficiencies by mode and fuel type. The net result was a database of fuel use and vehicle mileage by mode type among 907 transit agencies.

The NTD reports the following fuel types:

- Biodiesel (gallons),
- Compressed natural gas (gallon equivalents),
- Diesel (gallons),
- Electric battery (kWh),
- Electric propulsion (kWh),
- Ethanol (gallons),
- Gasoline (gallons),

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An Update on Public Transportation's Impacts on Greenhouse Gas Emissions

- Hydrogen (gallon equivalents),
- Liquefied natural gas (gallon equivalents), and
- Liquefied petroleum gas (gallon equivalents).

Emissions Factors

Emissions factors for direct, indirect, and upstream CO_2, CH_4, and N_2O emissions were applied to each fuel type (U.S. EPA 2020a, U.S. EPA 2020b, Wang et al. 2020). The electricity grid subregion emissions factors associated with the zip code of each transit agency's headquarters was used to calculate electricity emissions. Where appropriate, CH_4 and N_2O emissions were calculated on a per-vehicle-mile basis.

Transportation Efficiency: Calculating Avoided Emissions from Transit Passenger Travel

The net GHG benefits of transit as calculated for this project include the avoided GHG emissions of private automobile use by transit passengers, also called transportation efficiency. NTD-reported passenger mile data were the basis for this analysis, which was done using the calculations described here:

- Passenger miles × **mode shift factor** (0.329) = avoided vehicle miles.
- Avoided vehicle miles/miles per gallon (22.5, 2018 FHWA on-road light-duty vehicles) = avoided gallons of fuel.

The avoided vehicle miles and gallons of fuel were then used to calculate GHG emissions (see Appendix A).

Mode Shift Factor

One of the key GHG benefits of public transportation is that it enables passengers to avoid emissions that would have otherwise occurred if they had driven a private automobile. APTA calls this a "transportation efficiency" gain (APTA 2018). It may also be described as the direct effect of transit on vehicle miles traveled (VMT). The tradeoff between passenger miles and private automobile miles is not a 1-to-1 replacement. Some passengers would drive if they were not taking transit, but others would carpool, bicycle, walk, use a taxi, use a ridehailing service, or not take a trip at all.

Transit agencies conduct passenger surveys to understand the modes of transportation that passengers would choose if they were not taking a transit trip. This mode shift is an important factor in estimating the GHGs avoided by transit passengers (see Figure 2). APTA gathers passenger survey data from transit agencies and compiles them into a national average, which is what was used for this research.

An estimated 12% of passengers would use ridehailing if not on transit, 14% would otherwise drive alone, 10% would carpool (which is divided by 2.5 passengers per carpool for this analysis), and 3% would take taxis (APTA 2020). These data are used in the analysis to determine that for every 3 passenger miles on public transportation, 1 personal vehicle mile is avoided (**a mode shift factor of 0.329**). See Appendix A for more information.

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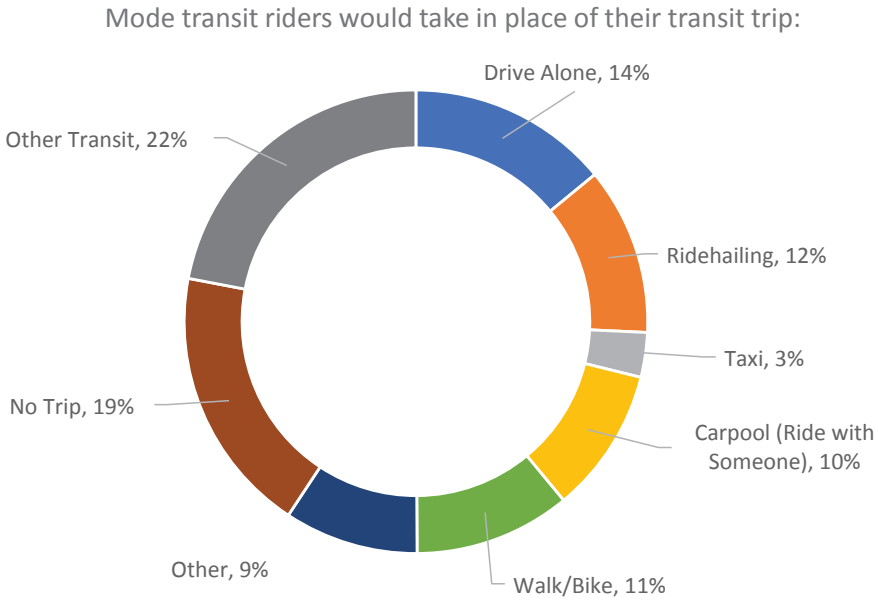

Source: APTA 2020, adjusted to include other transit modes.

Figure 2. Transit survey mode shift data.

Land Use Efficiency: Calculating Avoided Emissions from Community Travel

A significant body of research has shown that transit's impacts on emissions in a community expand beyond transit's passengers (Ewing et al. 2007). Transit investments, service improvements, and associated development can lead to location efficiency, where destinations like employment and shopping are closer to the households that need them [Ewing et al. 2015, Center for Neighborhood Technology (CNT) n.d.]. Residents in a location-efficient area are able to make shorter trips, fewer trips, or walk or bike to meet their daily needs (Ewing and Cervero 2010, Cervero and Murakami 2010). The GHG emissions savings associated with these impacts were calculated by transit agency using NTD-reported passenger mile data in the calculations described here:

- Passenger miles × mode shift factor (0.329) = avoided passenger vehicle miles.
- [(Avoided passenger vehicle miles × **transit multiplier**) – avoided passenger miles] = avoided community vehicle miles.
- Avoided community vehicle miles/miles per gallon (22.5 2018 FHWA on-road light-duty vehicles) = avoided gallons of fuel.

The avoided vehicle miles and gallons of fuel were then used to calculate GHG emissions (see Appendix A).

Transit Multiplier

The transit multiplier is the total VMT reduction associated with transit, including transportation efficiency and land use efficiency VMT savings divided by the transportation efficiency VMT savings to create a multiplier (see Figure 3). The multiplier allows the research findings about transit's impact on VMT in 28 communities to be applied to every transit agency in this study in a regionally specific way.

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$$\text{Transit multiplier} = \frac{(\text{transportation efficiency VMT}) + (\text{land use efficiency VMT})}{(\text{transportation efficiency VMT})}$$

Figure 3. Transit multiplier equation.

- **Transportation Efficiency:** VMT reduction of transit passengers (also called transit direct effect on VMT).
- **Land Use Efficiency:** VMT reduction in the community. Even residents who do not ride transit themselves save VMT, such as through shorter trips and fewer driving trips (also called transit indirect effect on VMT).

The transit multipliers for this study were developed using a multilevel structural equation model and a database of household travel survey data in 28 regions matched with socio-economic, built environment, and regional characteristics. The model found that the effect of transit in the community is much larger than the avoided auto use of transit passengers alone and that changes in the built environment in communities that are well served by transit create VMT savings several times larger than passenger impact alone.

The advantages of this modeling approach over previous studies include:

- The diverse set of regions examined allowed the researchers to study a wider variety of regional and local variables, and
- The household-level data allowed the researchers to deploy place-based characteristics to the model at a fine grain to better determine impact, which gives this work a validity that was missing from some of the earlier studies and allowed the researchers to calculate custom transit multipliers for the transit agencies in the analysis.

The range of transit multipliers calculated for this study was 5.97 to 13.04, with a **median value of 6.03**. The total impact across all transit agencies studied was equivalent to a multiplier of 8.35. Note that this is not the land use multiplier as usually defined, but a multiplier of total VMT reduction relative to VMT reduction due to transit passengers.

What does a transit multiplier of 6.03 mean? Consider a community with 1 million transit passenger miles. Using the transportation efficiency calculation and the mode shift factor of 0.329, it is estimated that those 1 million passenger miles avoided 329,000 personal vehicle miles. Applying the transit multiplier, this 329,000 VMT can be used to estimate the VMT avoided in the broader community by solving for land use efficiency in the equation in Figure 3.

(329,000 VMT × 6.03 transit multiplier) – 329,000 VMT

= 1,654,870 land use efficiency VMT savings.

So, taken together, that community with 1 million transit passenger miles saw a total reduction of 1,983,870 miles traveled by both transit passenger and broader community members. This value would match closely with that of previous studies, where for every 1 passenger mile

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of transit service there were 2 miles of vehicle travel avoided. An adjustment for vehicle occupancy is not required because there is an occupancy factor in the model that is used to develop the transit multiplier.

If the transit multiplier value in this hypothetical community were the maximum among the transit agencies of 13.04, the outcome would be 4.3 miles of vehicle travel avoided for every passenger mile of transit service, which is a significant impact that is within the range of values found in previous studies.

What the transit multiplier approach in this study allows that previous studies have not is to scale the multiplier for each transit agency using passenger miles and service area population to better estimate transit's impact. Furthermore, the transit multiplier is anchored in real-world data from a diverse set of 28 regions, which gives it a high degree of statistical certainty.

Because land use patterns take time to develop, the authors expect that areas with long-established transit and location-efficient land use patterns may see different impacts than areas with more recent changes. The authors also expect that regional variation may play a role. Due to the spatial overlap of transit modes within many regions, mode-specific transit multipliers were not developed as part of this study. Further unpacking of impacts using the transit multiplier modeling presented here is an area ripe for additional exploration.

Public Transportation Scenarios for 2030 and 2050

Using the findings of the GHG analysis for 2018, the authors created a set of hypothetical scenarios of transit emissions for 2030 and 2050 to highlight the potential impacts of public transportation climate action. The assumptions these scenarios use are described in Chapter 3. The scenarios are not forecasts, but rather conceptual "what ifs" for further electrification of transit, expansion of clean power adoption, and significant increases in transit ridership. The spreadsheet tool published as part of this project allows the user to try similar scenarios at the individual transit agency level.

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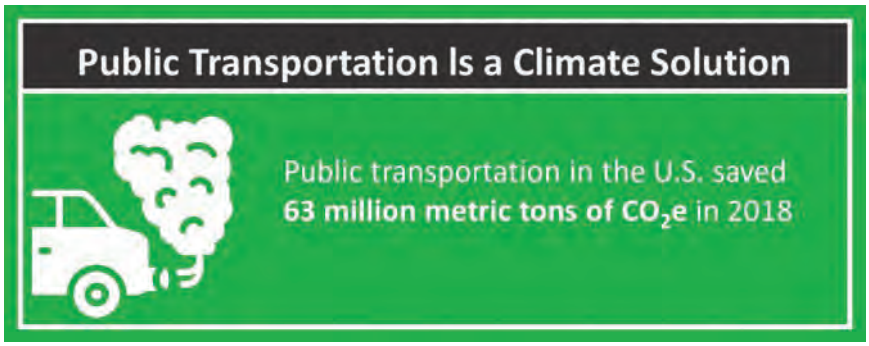
CHAPTER 3

National Sustainability Benefits of Public Transportation



Public Transportation's GHG Savings

Public transportation in the United States saved 63 million metric tons of carbon dioxide equivalent (MMT CO_2e) emissions in 2018—the equivalent of taking 16 coal power plants offline for a year (U.S. EPA 2020c). This study examined public transportation's impacts on GHG emissions by calculating the difference between transit vehicle GHG emissions (12 MMT of CO_2e) and GHG reductions associated with transit.

- **Transportation Efficiency GHG Savings:** The GHG emissions saved by passengers riding transit rather than using personal vehicles: **9 MMT CO_2e saved in 2018**. Transit passenger surveys show 33% of transit passenger miles would otherwise be replaced by personal vehicle miles (APTA 2020).
- **Land Use Efficiency GHG Savings:** The GHG emissions saved by the broader impact of transit on VMT in the community: **66 MMT CO_2e saved in 2018**. Even residents who do not ride transit themselves save GHGs because transit creates land use efficiencies, such as through shorter driving trips, fewer driving trips, and more trips on foot or by bicycle.
- **Net impact:** 12 MMT CO_2e emitted – 75 MMT CO_2e reduced = 63 MMT CO_2e.

Transit Vehicle GHG Emissions, 12 MMT CO_2e

Public transportation vehicles traveled 4.7 billion miles in 2018 using diesel fuel, gasoline, natural gas, hydrogen, liquefied petroleum gas, electricity, biodiesel, and ethanol. Public transportation consumed 837 million gallons of fossil fuels, 6.7 billion kilowatt hours (kWh) of electricity, and 137,559 gallons of hydrogen in 2018. Transit vehicle emissions include direct CO_2e emissions that occurred at the vehicle, indirect CO_2e emissions that occurred at power plants and during hydrogen production, and upstream CO_2e emissions from production and distribution.

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An Update on Public Transportation's Impacts on Greenhouse Gas Emissions

Public transportation in the United States used 49 million gallons of biodiesel fuel and 47 thousand gallons of ethanol in 2018 (FTA 2020a). The CO_2 emitted by these fuels is considered "biogenic" by major GHG accounting standards because it is sourced from plant matter and part of the natural carbon cycle, so it is tracked separately, while the CH_4 and N_2O emissions associated with these fuels is tracked as part of the overall vehicle GHG emissions (U.S. EPA 2016). Transit use of biodiesel and ethanol emitted 0.5 MMT biogenic carbon dioxide [CO_2(b)] in 2018.

Transit vehicle GHG emissions fell 19% from 2005 to 2008 even as transit passenger miles rose 9% over that period. The savings from 2005 to 2008 came from decreased fossil fuel use and an increased use of cleaner electricity. The average CO_2 per kWh fell 47% from 2005 to 2018, making electricity a much lower-carbon choice (Davis and Hale 2007).

Transportation Efficiency GHG Savings, 9 MMT CO_2e

Transportation efficiency GHG savings are from the avoided personal vehicle travel of transit passengers. Passengers rode public transportation 54 billion miles in 2018. Transit passenger surveys show 32.9% of transit passenger miles would otherwise be replaced by personal vehicle miles (APTA 2020). The term "personal vehicle" is used to indicate automobiles and light trucks and includes ridehailing and taxi vehicles for hire. The average personal vehicle on the road in 2018 had a fuel economy of 22.5 mpg.

Land Use Efficiency GHG Savings, 66 MMT CO_2e

Even residents who do not ride transit themselves save GHGs because transit creates land use efficiencies, such as through shorter driving trips, fewer driving trips, and more trips on foot or by bicycle. In 2018, these efficiencies avoided 131 billion miles of personal vehicle travel in communities with transit.

The combination of these three emissions impacts: transit vehicle GHG emissions (**12** MMT CO_2e) – transportation efficiency GHG savings (**9** MMT CO_2e) – land use efficiency GHG savings (**66** MMT CO_2e) = a net **63** MMT CO_2e savings impact of public transportation in 2018. That net savings is equivalent to 3% of U.S. transportation GHG emissions in 2018 (U.S. EPA 2020c). More information about public transportation GHG impacts by individual transit agency can be found in Appendix B and in the spreadsheet tool for this project.

Electric vehicles made up approximately 0.4% of all light-duty vehicles in 2018 [Edison Electric Institute (EEI) 2019 and FHWA 2019a]. The GHG savings here do not include electric personal vehicles due to lack of data about the location of electric vehicles and their limited prevalence in 2018. At the national average emissions factor for electricity and a presumed average efficiency of 30 kWh per 100 miles of travel, the inclusion of electric vehicles would have reduced the transportation efficiency GHG savings by 29,052 metric tons (MT) CO_2e, or 0.3% of the 9 MMT CO_2e total. The inclusion of electric vehicles would have reduced the land use efficiency GHG savings by 213,514 MT CO_2e, or 0.3% of the 66 MMT CO_2e total. This will become a more important element of public transportation's GHG impact in the future as electric vehicles become more common for personal use.

Figure 4 shows public transportation's 2018 GHG impacts, with transit vehicle emissions on the left and the reductions associated with transit on the right. When the emissions and reductions are added together, the net savings is 63 MMT CO_2e. This study takes into account the full life cycle of transportation fuels (see Figure 4), as follows:

- **Direct** CO_2e emissions at the vehicle.
- **Indirect** CO_2e from power plants and hydrogen production facilities.
- **Upstream** CO_2e from fuel production and distribution.

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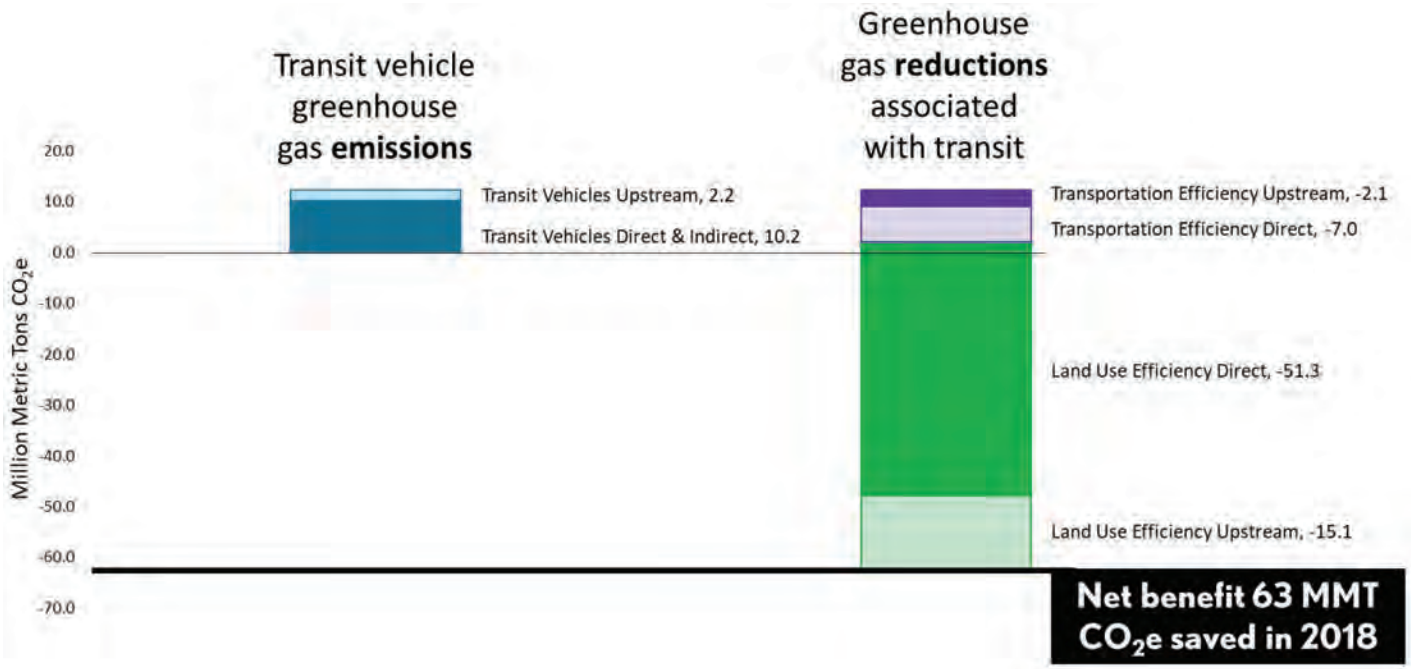

Figure 4. Public transportation GHG impacts, 2018.

Public Transportation's VMT and Fuel Impacts

Communities with public transportation avoided 148 billion miles of personal vehicle travel in 2018 through transportation efficiency and land use efficiency savings. That was 5% of the 3 trillion total U.S. vehicle miles that year, but in transit-rich areas, it can be a much larger share of total travel. The personal vehicle miles savings include vehicle trips avoided by transit passengers and vehicle trips avoided in communities with transit due to location efficiency and other transportation and land use factors. This value was calculated using the methods identified in Chapter 2. Transit vehicles traveled 4.7 billion miles in 2018, and the average transit vehicle had 12 passengers. For comparison, average private vehicle occupancy for commute trips was 1.18 passengers, and for all trips was 1.67 passengers (FHWA 2018).

Public transportation helped avoid 6.6 billion gallons of gasoline use in 2018 through transportation efficiency and land use efficiency savings, and transit vehicles used significantly less energy than that—837 million gallons of fossil fuels, 49 million gallons of biodiesel and ethanol, and 6.7 billion kWh of electricity.

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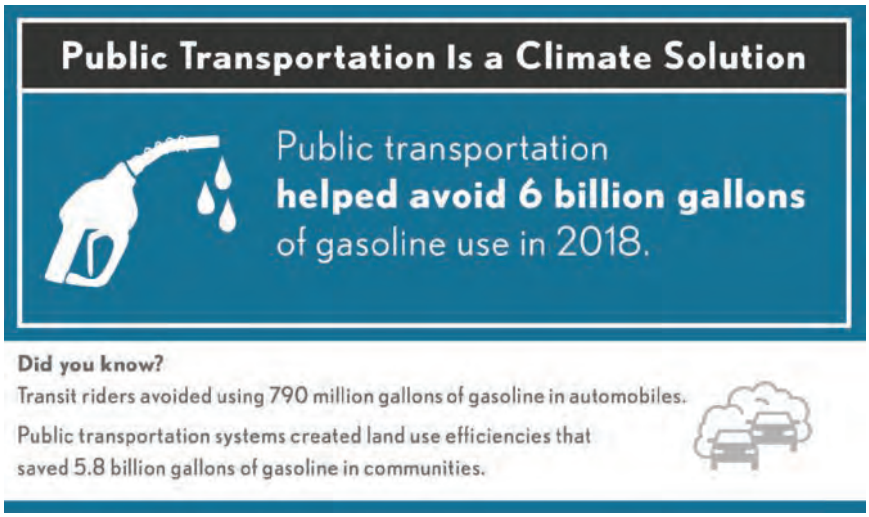
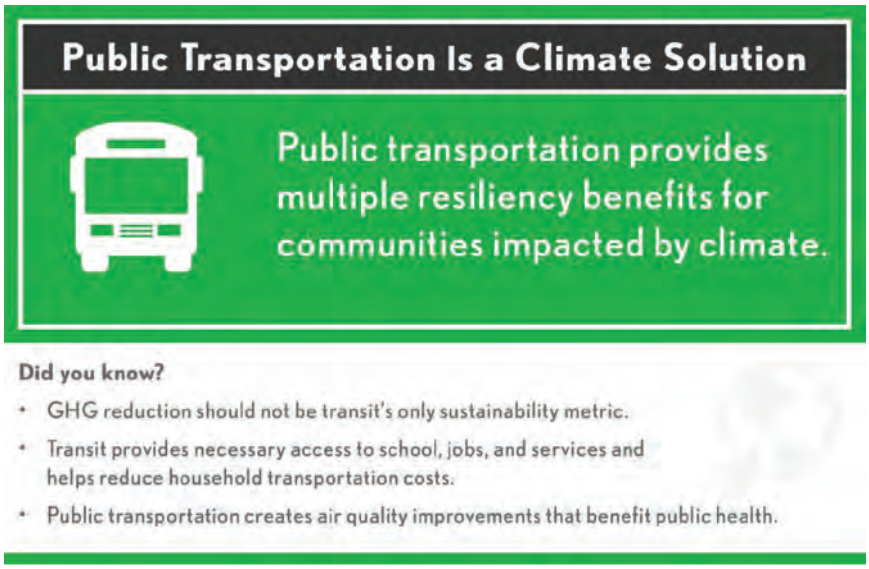


Transit's Transportation Efficiency Impact, or the avoided personal vehicle travel of transit passengers, was 17.8 billion miles of vehicle travel and 790 million gallons of fuel use in 2018 based on 54 billion total transit passenger miles, a mode shift factor of 0.329 and an average personal vehicle fuel economy of 22.5 mpg. That represents $1.7 billion in annual fuel cost savings at current fuel prices, or $2.2 billion at 2018 fuel prices [Energy Information Administration (EIA) n.d.].

Transit's Land Use Efficiency Impact, or the avoided vehicle miles in the communities where transit operates, was 131 billion miles of vehicle travel and 5.8 billion gallons of fuel use in 2018 based on 17.8 billion avoided personal vehicle miles among transit passengers and a transit multiplier of 8.35 across all transit agencies (17.8 billion × 8.35 − 17.8 billion = 131 billion). That represents $12.2 billion in annual fuel cost savings at current fuel prices, or $15.8 billion at 2018 fuel prices (EIA n.d.).

Importance of Equity and Health



The transportation and land use efficiency enabled by public transit and the resulting fuel savings create many other sustainability benefits that were outside of the scope of this

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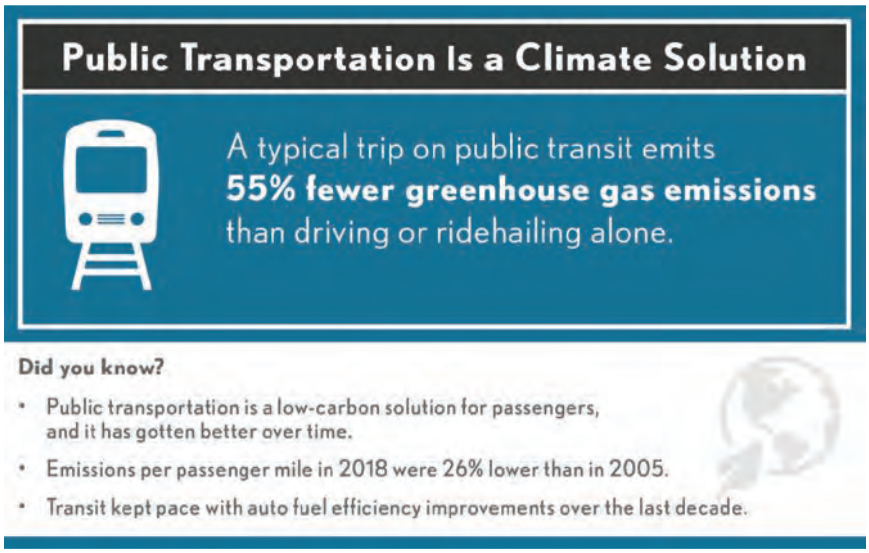
An Update on Public Transportation's Impacts on Greenhouse Gas Emissions

analysis but are extremely important for communities. These include a reduction in criteria air pollutant emissions that have an impact on health, traffic safety improvements as fewer residents drive, and health benefits as more residents walk and bicycle to transit and in place of driving for shorter trips in location-efficient areas. The health impacts of our transportation choices are also important to consider. Studies show that air pollution and living near busy roads contribute to respiratory and cardiovascular health problems, including asthma in children (Health Effects Institute 2010, Chen et al. 2015). Investment in public transportation can reduce air pollutants in addition to GHGs and make the air safer for those at risk.

Public transportation serves many essential community needs, so while its role as a climate solution is important, GHGs are not the only metric that should be used to measure transit success. Every transit passenger is traveling for a reason, and equity and transportation access require that transit service be available to meet the needs of seniors, shift workers, students, and others who may not ride the highest-occupancy routes or at peak commute times. Measured by CO_2e per passenger mile alone, these routes may look like they perform less well, but incorporating metrics like access to jobs or travel time to low-cost grocery stores may show these to be high-priority routes.

Sustainability is not a one-dimensional concept, and public transportation contributes to community resilience in multiple ways beyond its carbon savings, such as by reducing household transportation costs (CNT n.d.). As communities look to public transit investment as a climate solution, the full spectrum of equity and resilience impacts of transit should be part of that decision making. Planning for a sustainable, resilient future must include public transportation that serves community needs.

Reduced Carbon Footprint of Individuals Using Public Transit



Public transportation helps passengers reduce their carbon footprint. Passengers contributed 55% fewer GHGs per mile by riding transit in 2018 than those driving or ridehailing alone.

Public Transportation Emissions averaged 0.23 kg CO_2e per passenger mile across all transit modes in 2018 including direct, indirect, and upstream GHG emissions.

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The Average Light-Duty Personal Vehicle Emissions—a weighted average of passenger cars, pickup trucks, vans, and sport utility vehicles—was 0.51 kg CO_2e per mile of direct, indirect, and upstream GHG emissions at 22.5 mpg (FHWA 2019a).

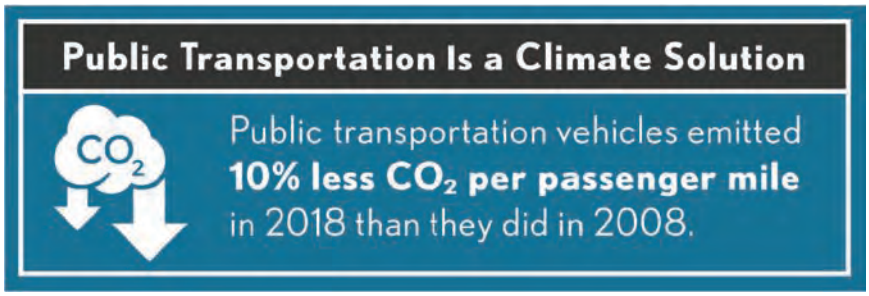
What about carpooling? A two-person carpool cuts vehicle emissions per person in half to 0.25 kg CO_2e per mile each, which remains slightly higher than the public transportation average of 0.23 kg CO_2e per passenger mile.

The 2017 National Household Travel Survey found that the typical commute trip in a personal vehicle had 1.18 passengers, and the average trip of any purpose, including shopping, recreation, or errands, had 1.67 passengers (0.43 kg CO_2e per passenger mile and 0.30 kg CO_2e per passenger mile, respectively) (FHWA 2018). By those measures, typical personal vehicle trips had higher emissions per person per mile than riding transit.

The average light-duty vehicle traveled 11,556 miles in 2018. A person driving that distance alone would have had a transportation GHG footprint of 5.9 metric tons of CO_2e per year as compared to 2.6 metric tons of CO_2e if transit had been used. An average U.S. household would have to cut its electricity use in half to achieve those same GHG savings at home (U.S. EPA 2020c).

These figures are for a gasoline-powered personal vehicle. Depending on the source of electricity, the emissions profile of an electric car can be significantly lower. In 2018, there were an estimated 1 million electric vehicles on the road—approximately 0.4% of all light-duty vehicles (EEI 2019 and FHWA 2019a). An electric car emitted 0.14 kg CO_2e per mile in 2018 at the U.S. average emissions factor for electricity and a fuel efficiency of 30 kWh per 100 miles. Depending on the electricity grid subregion supplying the electric vehicle, emissions per mile could have ranged from 0.04 to 0.24 kg CO_2e per mile. This range is similar to the per-passenger emissions of a battery electric bus in 2018. Of note, fuel economy improvement in personal vehicles can have a mixed effect on overall emissions if it induces more automobile travel (Munyon et al. 2018).

Emissions per Passenger Mile by Transit Mode



Public transportation is a low-carbon solution for passengers, and it has gotten better over time. Compared against two previous studies, emissions per passenger mile in 2018 were 26% lower than in 2005 (Davis and Hale 2007) and 10% lower than 2008 (FTA 2010). Slight differences in research methodology between those studies make those two values not directly comparable, but both indicate that today's transit is lower carbon than it was in the past.

Figure 5 shows that rail modes have seen the largest savings in GHG per passenger mile, but the carbon efficiency of bus ridership has improved as well as transit agencies have adopted new technologies, fuels, operations, and practices. All in all, transit kept pace with private auto efficiency improvements over the decade of 2008 to 2018.

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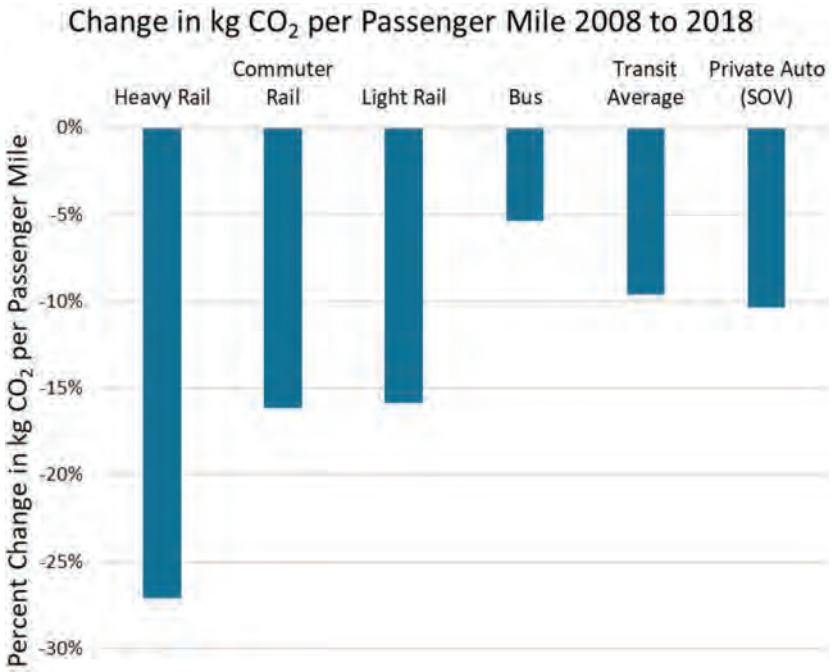
An Update on Public Transportation's Impacts on Greenhouse Gas Emissions



Note: Values in are in CO_2 not CO_{2e} in this chart only for consistency with previous analysis; private auto value in terms of single occupancy vehicle (SOV).

Figure 5. Change in transit GHG emissions per passenger mile 2008 to 2018.

In 2018, the most carbon-efficient modes on a per-passenger-mile basis were rail transit modes, which also transported 60% of passenger miles (Figure 6). Buses varied in emissions efficiency depending on fuel, technology, operations, and occupancy. Electric and biodiesel buses had the lowest GHG emissions per passenger mile in 2018 among all buses. Passengers on ferries and vans had higher emissions profiles, but those modes only accounted for 5% of passenger travel in 2018.

The lowest-emitting transit mode on a per-passenger-mile basis was heavy rail at 0.08 kg CO_2e per passenger mile. Heavy rail's emissions profile was driven by its high average occupancy (48% of revenue seat miles) and all-electric power source. The electricity powering heavy rail had average GHG emissions of 0.32 kg CO_2e per kWh, which was less than the national average of 0.43 kgCO_2e per kWh but similar to other transit averages.

Vans had high emissions on a per-passenger-mile basis, but much of that is a factor of their small number of seats compared to other transit vehicles and their relatively low occupancy. The typology for this study classifies transit vehicles from automobiles to cutaways as "vans." The average van in 2018 carried just two passengers per vehicle, as compared to over eight for a bus. Vans often provide essential accessibility services, so their efficiency should not be judged without considering their purpose.

Ferryboats were the highest emission mode per passenger mile at 1.0 kg CO_2e per passenger mile in 2018; however, ferryboats are not a large source of transit emissions overall—just 4% of the total in 2018. Only 27 transit agencies operated ferryboats in 2018.

Transit passengers took 4.7 billion trips on buses in 2018, the most of any public transportation mode. The emissions profile of those trips varied with the fuel and technology of the bus. A typical passenger bus trip in 2018 was 4 miles. The emissions for that trip were 1.4 kg CO_2e per passenger in an average transit bus, but just 0.5 kg CO_2e per passenger in an average battery electric bus, although that trip could have ranged from 0.1 to 0.9 kg CO_2e per passenger based on

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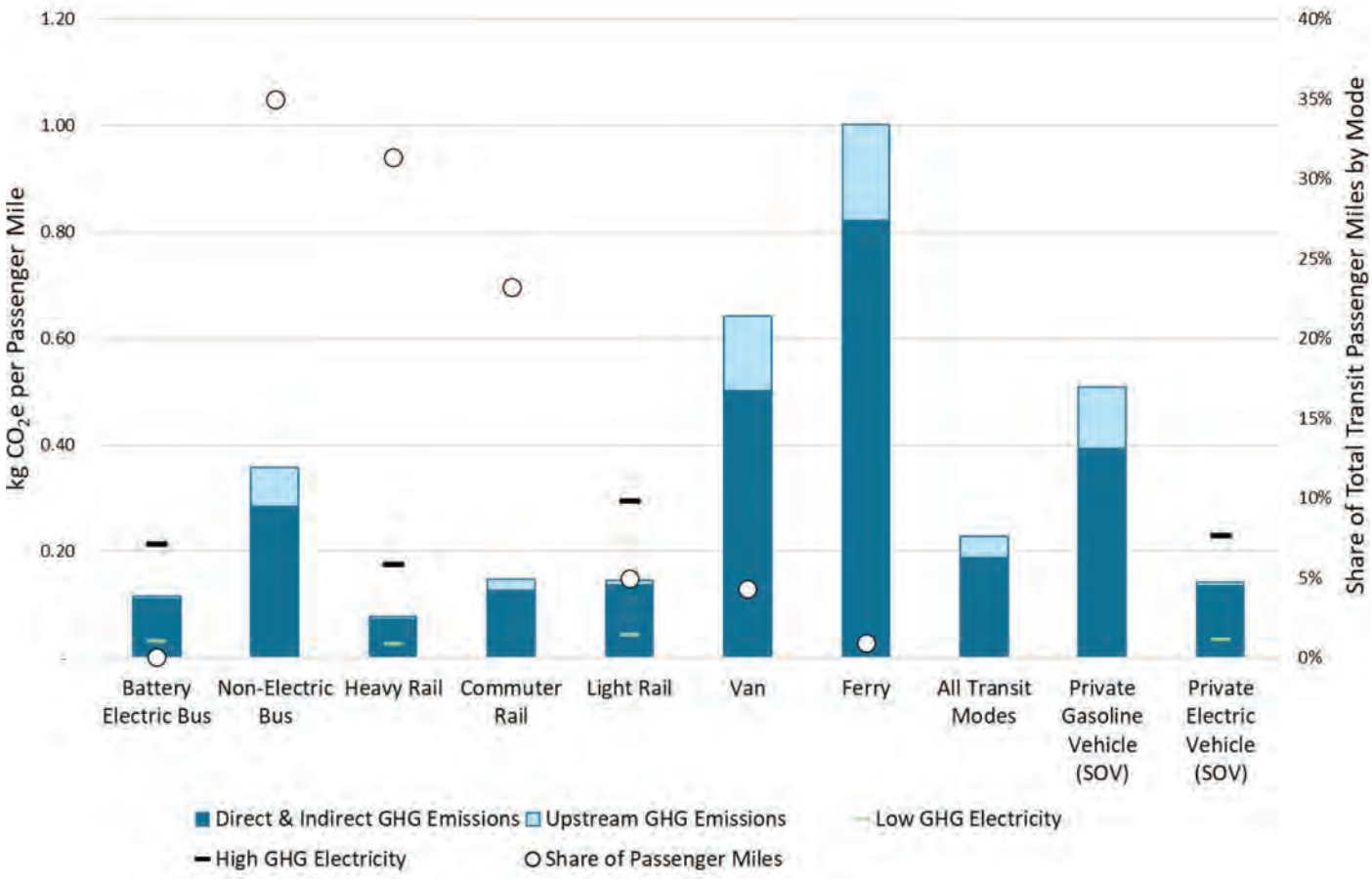
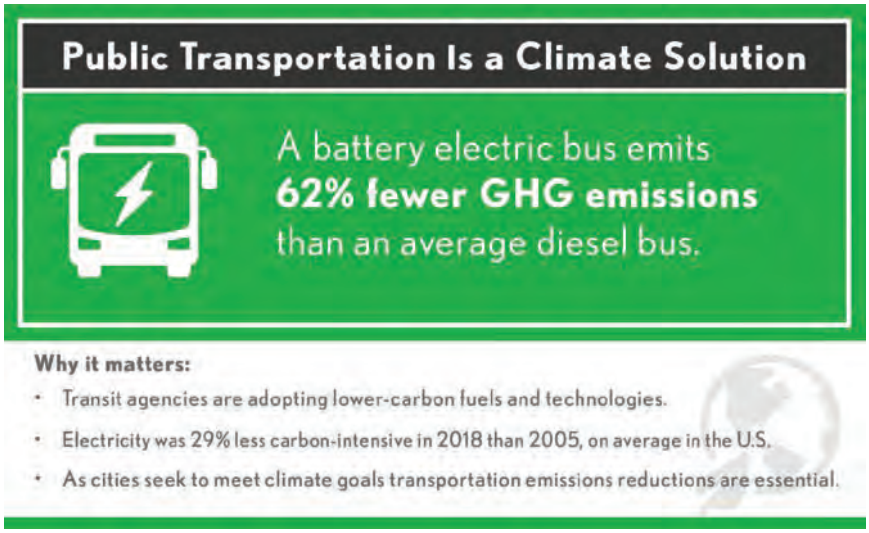


Figure 6. Average GHG emissions per passenger mile by mode.

the electricity sources in their area (Figure 6). Emissions per passenger mile broken out by individual transit agency and mode can be found in Appendix B and this project's spreadsheet tool.

Transit Agency Contributions to GHG Emission Reduction and Sustainability



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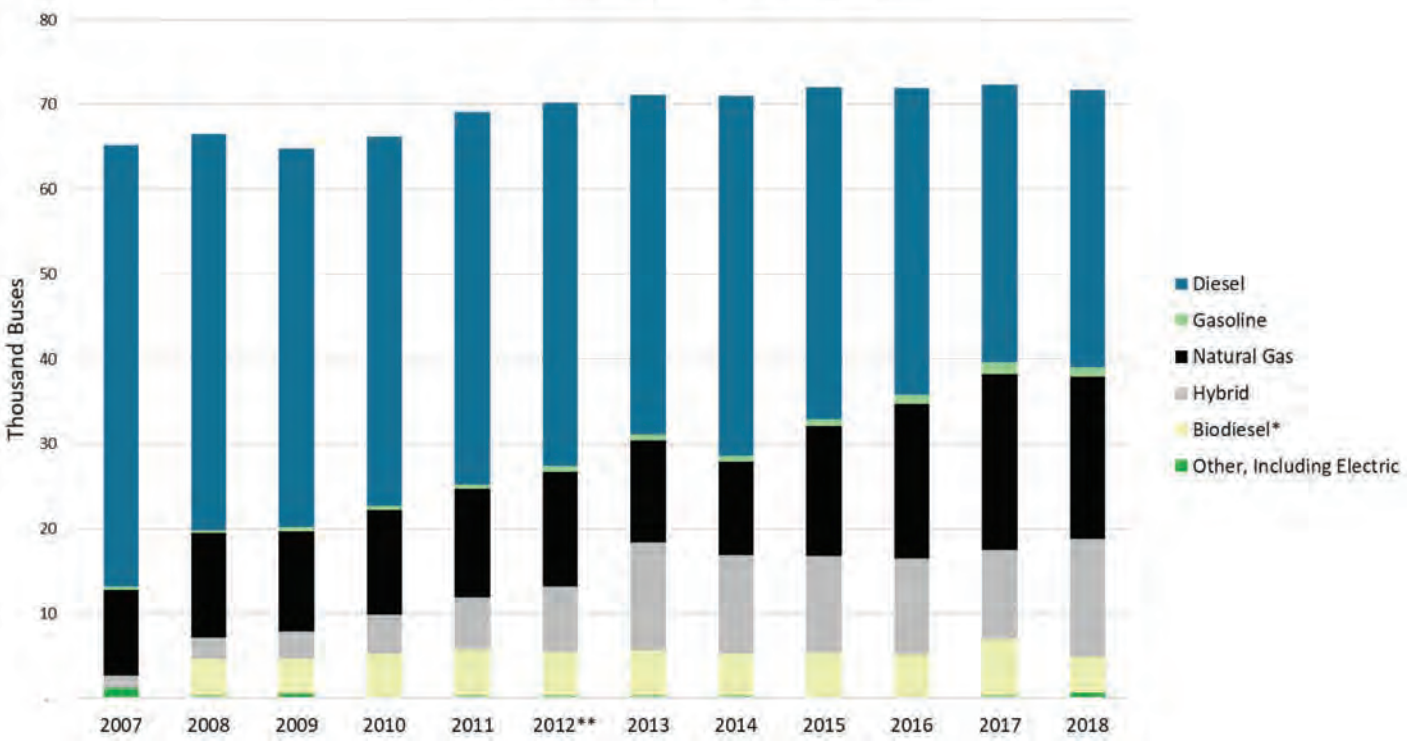
Transit agencies are taking climate actions. Transit GHG emissions have fallen over the past 15 years on both an overall basis and a per-passenger-mile basis. Even those that are not setting specific GHG targets are pursuing fuel efficiency and cost savings that can bring GHG saving along with them. Transit agencies are adopting lower-carbon vehicle technologies and fuels, such as hybrids, regenerative braking, biofuels, and electric vehicles. The growth of electric buses in recent years has been notable and especially beneficial as more carbon-intensive grid electric power sources like coal have been replaced by renewable solar and wind. *TCRP Research Report 219: Guidebook for Deploying Zero-Emission Transit Buses* provides detailed information for transit agencies looking to pursue this option (Linscott and Posner 2020).

Looking forward, a continuation of these trends will ensure that transit continues to be a low-carbon solution to meeting transportation needs. This will be even truer if ridership and occupancy increase over time. However, decreases in ridership, whether due to COVID-19 creating lasting disruptions in our travel patterns or scaling back of transit service, will shrink transit's GHG benefits. *TCRP Research Report 209: Analysis of Recent Ridership Trends* presents a detailed description of factors that can increase ridership, including increased service in transit-oriented areas (Watkins et al. 2020). Nevertheless, transit will continue to provide other resilience benefits in terms of essential mobility and access to communities that are otherwise made vulnerable by age, income, disability, neighborhood disinvestment, or other forces that may also put them on the front lines of climate disruption.

Bus Fleets Are Moving to Lower-Carbon Fuels and Technologies

In recent years, a significant share of the transit bus fleet has shifted away from traditional diesel technology, and this is contributing to emissions reductions. Figure 7 from the Alternative



Source: U.S. Department of Energy 2020. Notes: 2018 NTD data used elsewhere in this report include 628 electric propulsion buses not represented in the Figure 7 dataset. *Biodiesel counted as other in 2008. **2012 data estimated.

Figure 7. Transit bus fleet by fuel type, 2007–2018.

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Fuels Data Center shows counts of public transportation buses by fuel and technology from 2007 to 2018 using data from APTA's *2019 Public Transportation Fact Book* (APTA 2019).

These data show that the adoption of hybrid vehicles has been growing in recent years. Hybrid buses may still use diesel fuel but use it more efficiently. The adoption of natural gas and biodiesel fuel alternatives are also notable. The recent rise in electric bus technology is still small compared to the overall fleet but was starting to be noticeable in 2018.

Figure 7 is included because it has a useful temporal perspective on the public transportation bus fleet, but it should be noted that it uses a slightly different dataset than that used for the analysis in this report. The NTD data used for this study show 363 electric battery buses being used by 44 transit agencies over 4 million miles in 2018; an initial examination of 2019 NTD data show this grew to 547 electric battery buses traveling 7 million miles. That is a striking increase from 2015 NTD data, which show 114 electric battery buses.

Transit agencies have indicated success with electric battery bus adoption, citing the lower energy cost and reduced maintenance needs as particularly beneficial, although the up-front capital cost of electric vehicles and charging infrastructure remains a barrier to broader adoption. Electricity pricing structures also affect cost effectiveness, and high demand charges or time of use variability mismatched to transit agency needs may need to be addressed to make electrification viable in some communities.

Battery electric buses have many co-benefits, including noise reduction, zero tailpipe criteria air pollutant emissions, and an association with innovation that are appealing to many stakeholders. Cold weather performance is a limitation of battery electric buses today, but operational solutions can extend vehicle range, including preheating vehicles at the garage and deploying charging stations along routes. Electric transit vehicle technology is improving rapidly and may become an even better choice for communities in coming years.

Electricity Is Getting Cleaner

The rise in electricity as a public transportation fuel is reducing GHG emissions because, on average, electricity in the U.S. is becoming less carbon intensive. As fossil fuel power production is retired and new renewable sources come online, the average CO_2e per kWh of electricity used in the U.S. is going down.

Figure 8 shows the relevant electricity emissions factors. (Black dots are average; gray dots are ranges for all grid subregions.) The two values on the left outlined in the blue rectangle are the U.S. average for all electricity in 2005 and 2018. In 2005, electricity use in the United States contributed 0.61 kg CO_2e per kWh (excluding upstream emissions). In 2018, that fell to 0.43 kg CO_2e per kWh, a 29% reduction.

Not only is electricity getting cleaner, but transit service is often powered by lower-carbon electricity. Comparing the two values outlined by the green dashed rectangle in Figure 8 shows that transit vehicles in 2018 used electricity that emitted 0.32 kg CO_2e per kWh on average. This is 26% better than the U.S. average electricity emissions rate in 2018. Battery electric buses had a slightly higher average emissions rate at 0.40 kg CO_2e per kWh. Electric propulsion buses had a rate of 0.27 kg CO_2e per kWh. On average, rail vehicles had an emissions rate of 0.32 kg CO_2e per kWh. This cleaner-than-average electricity contributes to transit's climate benefits.

Some transit agencies are also generating renewable power to lower their emissions even further, or making clean power purchases, but this study uses U.S. EPA Emissions and Generation Resource Integrated Database (eGRID) subregion electricity emissions factors (U.S. EPA. 2020a) for all transit agencies because there is no national data source on transit agency clean power procurement.

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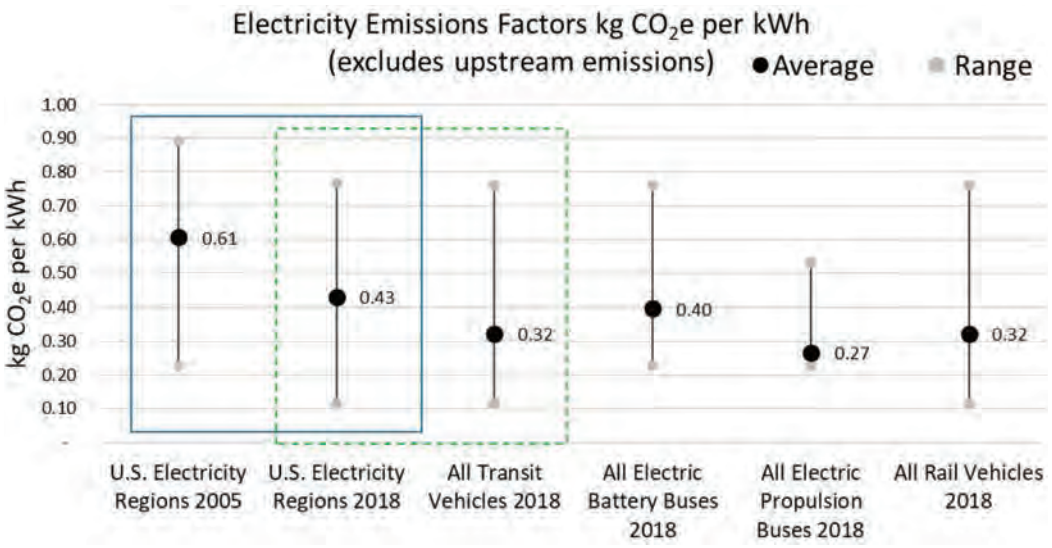

Note: Ranges indicate highest and lowest eGRID (U.S. EPA. 2020a) subregion GHG values.

Figure 8. Electricity emissions factors kg CO_2e per kWh.

Transit Vehicle Emissions by Fuel

Heavy rail and light rail systems were all powered by electricity in 2018 and had GHG emissions per vehicle mile of 1.85 and 2.92 kg CO_2e per vehicle mile, respectively, including both direct and upstream emissions.

Commuter rail systems used several different fuels in 2018. Biodiesel commuter rail emitted 2.32 kg CO_2e per mile plus 5.89 kg of CO_2(b), diesel commuter rail emitted 6.28 kg CO_2e per mile, and electric commuter rail emitted 2.71 kg CO_2e per mile on average.

Emissions per vehicle mile metrics across modes are not apples-to-apples comparisons because the vehicles have varying occupancy. Commuter rail averaged 92 seats per vehicle, while heavy rail averaged 49, and light rail averaged 58. The average bus had 35 seats in 2018. To enable a comparative look at fuel performance within a single mode, the fuel discussion in the remainder of this section focuses on buses.

Diesel fuel remained the most common bus fuel in 2018, and diesel buses emitted 3.05 kg CO_2e per mile. The next most common fuel was compressed natural gas (CNG), which emitted 3.46 kg CO_2e per mile—a metric affected by the life-cycle emissions properties of the fuel and the fuel economy of the vehicles it is used in. On a per-energy-unit basis, CNG has a lower carbon footprint than diesel, but the energy use and vehicle mileage metrics reported in the NTD indicate a lower vehicle fuel efficiency for CNG buses. This may be influenced by the growing use of hybrid diesel technology.

In 2018, the average biodiesel bus had lower GHG emissions per mile than any other fuel type, at 0.92 kg CO_2e per mile (see Figure 9); however, biodiesel direct CO_2 emissions are considered biogenic so are tallied separately in most GHG assessments, which added another 2.32 kg CO_2(b) per mile to those buses.

The average battery electric bus emitted 0.97 kg CO_2e per mile. Electric propulsion was also efficient at 1.90 kg CO_2e per mile on average. The ranges of reported efficiency for these fuels in the NTD are significant, however, and the varying emissions rates of electricity by region contributed to a wide variability of CO_2e per mile seen in the electric-powered buses.

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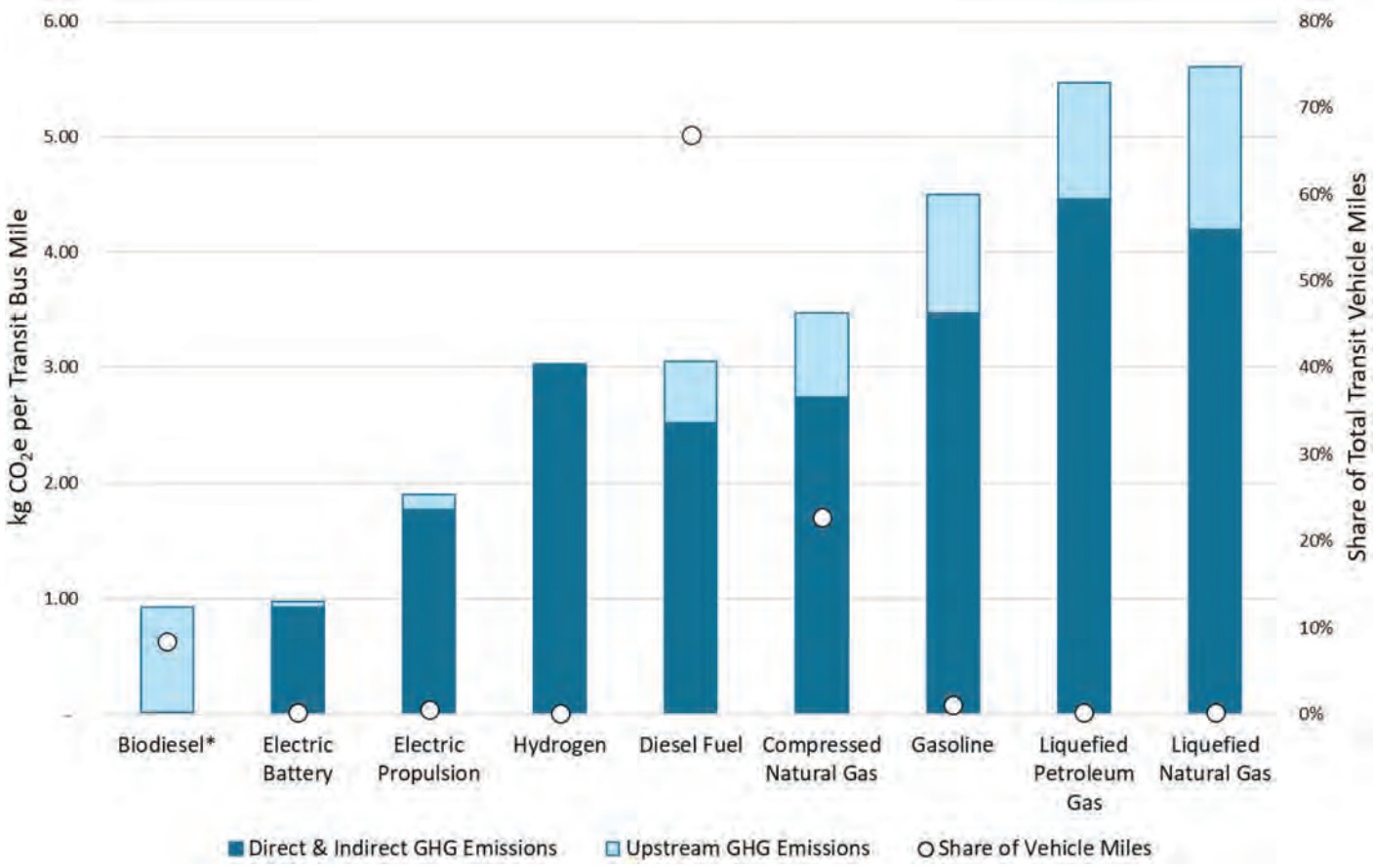

*Biodiesel also generates CO_2(b) of 2.32 kg per bus mile.

Figure 9. Average transit bus GHG per mile by fuel.

Hydrogen was used as a fuel by only four transit agencies in the 2018 NTD dataset. The emissions value used here is for hydrogen produced from natural gas. Hydrogen produced from renewable electricity has a much lower emissions rate, but the NTD data do not indicate hydrogen sources, so the most common source was used in this analysis.

Gasoline, liquefied petroleum gas (LPG), and liquefied natural gas (LNG) were all rarely used for transit buses, and buses using these fuels had higher emissions per mile than other fuels.

Many factors contribute to the CO_2e per mile of buses beyond the carbon content of the fuel. Vehicle size, occupancy, traffic congestion, state of good repair, wait times, driving speeds, and even weather can have an impact on fuel economy and thus GHG emissions. Transit agencies are making significant investments in these operations factors that affect GHG emissions and should continue to do so.

Right-sizing transit vehicles to the community's needs is also important. While high-occupancy routes in dense areas may fill up an extra-long articulated bus at rush hour, that may not be the right vehicle for other routes, and in small communities, a van may meet passenger needs. The average gasoline van in this study had a fuel efficiency of 9.1 miles per gallon in 2018 as compared to 4.1 miles per gallon for the average diesel bus.

However, improving carbon efficiency is not just a matter of reducing bus size—increasing ridership along with occupancy has the added benefit of reducing net emissions in the community. As more people ride transit, more personal vehicle miles are saved.

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National Sustainability Benefits of Public Transportation by Mode

Adding together the three categories of GHG impacts (transit vehicle emissions + transportation efficiency + land use efficiency), heavy rail has the largest net GHG savings overall at 30 MMT CO_2e (see Figure 10). The GHG benefits of heavy rail come in part because of its electric fuel and in part because of its relatively high average occupancy (48%), but also because of its strong ridership at 17 billion passenger miles. Heavy rail is located in communities with high transit multipliers on average; heavy rail strongly affects the land use patterns in the communities in which it operates and is located in denser places.

Transit buses had the largest share of passenger miles of any mode in 2018, with 19 billion passenger miles, and the second largest net GHG impact at 16 MMT CO_2e. Buses saved somewhat fewer emissions than heavy rail because buses are a different technology; they had lower occupancy, at 24%, so more vehicles were needed to carry passengers; many buses in 2018 were diesel fueled, a more carbon-intensive fuel than electricity; and buses operate in more places with a lower average transit multiplier than heavy rail.

The other modes had GHG impacts in line with the passenger share in 2018: commuter rail saved a net 13 MMT CO_2e in 2018, light rail saved 3 MMT CO_2e, vans saved 1 MMT CO_2e, and ferryboats saved just 0.03 MMT CO_2e.

Emissions by Transit System Size

There were 31 transit agencies in 2018 that had ridership between 250 million and 12 billion passenger miles. These largest transit agencies represented 78% of transit passenger ridership in 2018 (Table 1, column 2) but only 58% of the GHG emissions from transit vehicles.

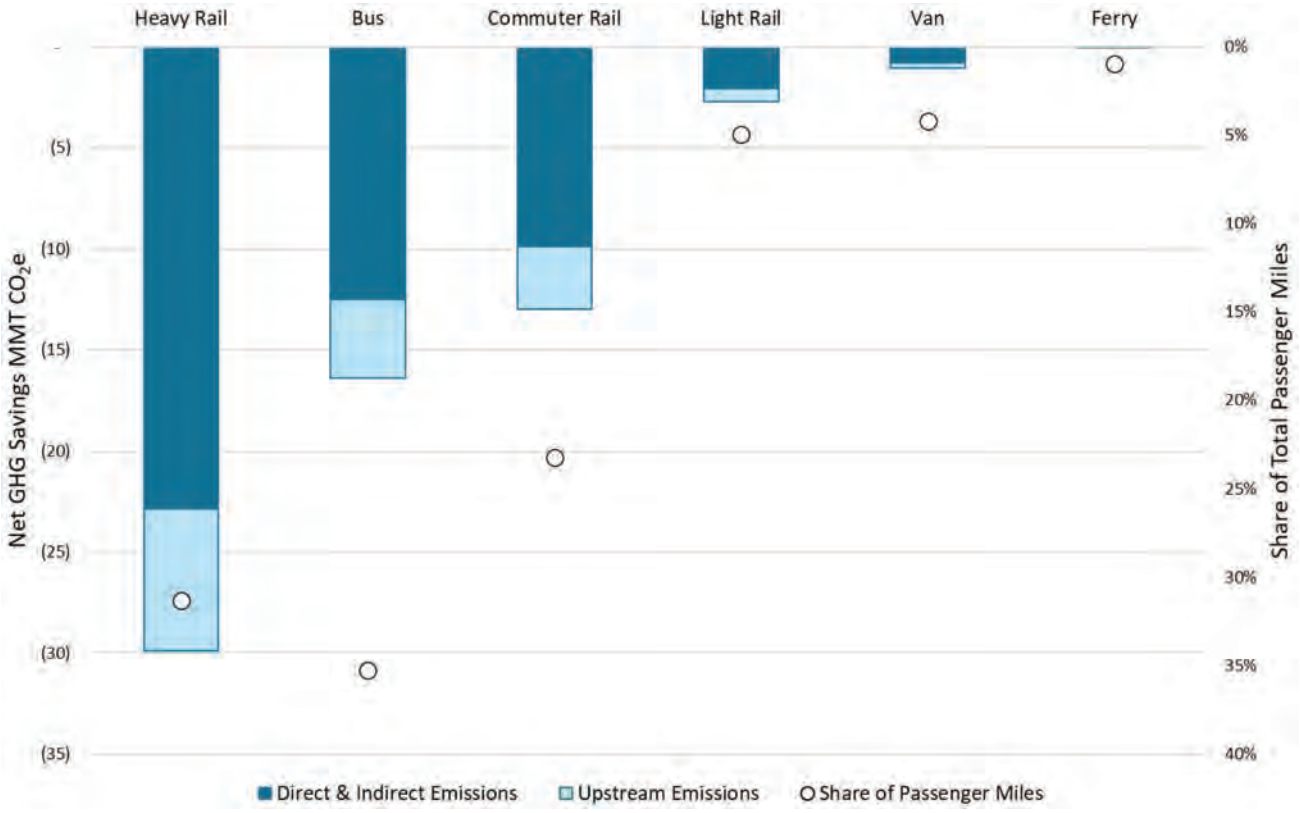

Figure 10. GHG impacts of public transportation by mode, 2018.

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Table 1. Transit average GHG metrics by transit agency size, 2018.

Column #	1	2	3	4	5	6	7	8
	All Modes			All Buses			Diesel Buses	
2018 Passenger Miles	Count of Transit Agencies	Share of Passenger Miles	CO_2e per Passenger Mile	CO_2e per Passenger Mile	Median Bus Occupancy	CO_2e per Vehicle Mile	Fuel Economy (mpg)	CO_2e per Vehicle Mile
250 million to 12 billion	31	78%	0.16	0.30	27%	3.2	3.6	3.4
50 million to 249.9 million	67	13%	0.39	0.39	21%	2.8	4.5	2.8
4,000 to 49.9 million	809	9%	0.56	0.49	14%	2.8	4.4	2.9

Emissions among larger transit agencies are lower, in part, because these agencies are more likely to operate rail modes than are smaller transit agencies. For example, 11 heavy rail systems are operated by the largest transit agencies and have a median emissions of 0.10 kg CO_2e per passenger mile. Small and mid-sized transit agencies operated four heavy rail systems that had a median of 0.16 kg CO_2e per passenger mile, a metric that is affected by electricity emissions rates and transit vehicle occupancy.

Comparing on an apples-to-apples vehicle basis of bus performance, the largest agencies also had lower average GHG emissions per bus passenger mile (Table 1, column 4), but they had the highest average CO_2e per vehicle mile (Table 1, column 6). What are the reasons for these differences? Factors affecting efficiency include fuel type, technology, operating conditions, and ridership.

Among buses using the same fuel, GHG performance per vehicle mile is directly linked to fuel economy. Looking at diesel-fueled transit buses in particular, large transit agency diesel buses had lower fuel economy and higher GHG emissions per mile on average (Table 1, columns 7 and 8). Some elements of this fuel economy difference include:

- **Vehicle Size.** Buses operated by larger transit agencies are bigger—41 seats per bus as compared to 38 among mid-sized transit agencies and 29 among smaller transit agencies.
- **Vehicle Speed.** Fewer data are available on operating conditions, but larger transit agencies typically operated in denser areas, had more passengers boarding, and had slower average bus speeds than mid-sized and smaller transit agencies.
- **Vehicle Technology**. The larger transit agencies operated hybrid diesel buses more frequently in 2018 (24% of diesel bus miles as hybrid among the largest transit agencies, compared to 10% and 14% among mid-sized and small transit agencies), which is a countervailing element to the previous two described. The use of hybrid technology and regenerative braking improve fuel efficiency. Without the adoption of hybrid technology, many larger transit agencies would have had less-efficient diesel buses on average and higher GHG emissions.

Passenger mile data are not available by fuel type in the NTD, but when ridership and occupancy are taken into account, buses that carry more passengers create CO_2e efficiencies per passenger mile. This is multiplied when one takes into account the transportation efficiency and land use efficiency GHG savings discussed elsewhere in this report.

What this means for communities and transit agencies working to design climate solutions is that public transportation is a climate solution, but its climate benefits can be strengthened by increasing ridership and occupancy, using vehicles efficiently, improving fuel economy,

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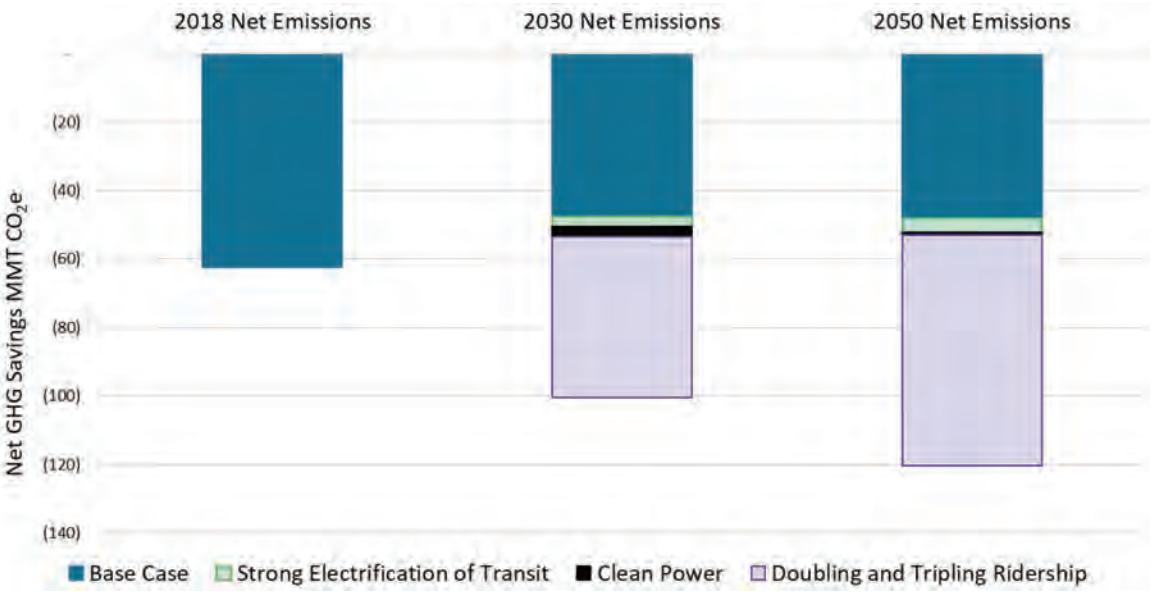

Figure 11. Public transportation scenarios for 2030 and 2050 (hypothetical for consideration).

choosing low-carbon fuels and technologies, and supporting efficient transit operations. Some other efficiency improvements may include public on-demand service where route-based service is not a good match to community needs and low-carbon microtransit options such as providing shared electric bicycles and scooters as part of transit service.

A high-level set of scenarios for public transportation's potential future were created to highlight the elements of climate impact for transit agencies (see Figure 11). These scenarios are not meant to be predictive but rather serve as hypotheticals for consideration and to provide more information to conversations about public transportation climate action.

Public Transportation Scenarios for 2030 and 2050

Business as Usual Base Case

As a business-as-usual base case looking to 2030 and 2050, it is expected that transit vehicle technologies will continue to improve, and fuel economy will increase. Given current trends in technology and fuel adoption, it is anticipated that electrification will continue (0.5% per year), and that the use of hydrogen and biofuels will increase to a small degree (0.2% per year). The base case assumes a 2% annual decarbonization of electricity based on recent trends (U.S. EPA 2020a).

The base case assumes a ridership recovery from the COVID-19 period and a slight increase in ridership from 2018 to 2030 and beyond. Passenger ridership and fuel economy assumptions for transit vehicles and personal vehicles follow the assumptions in the EIA's *Annual Energy Outlook 2020* (EIA 2020). The net result of this future-year analysis of current trends is that public transportation continues to have significant GHG benefits under business as usual.

Ridership Increases GHG Benefits

A hypothetical set of scenarios was created that included three types of climate action: electrification, zero-carbon electricity, and increased ridership. The largest GHG change under the scenarios is avoided personal vehicle travel as ridership doubles and triples. Avoided personal

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vehicle travel creates net savings of 120 MMT CO_2e via transportation and land use efficiency in 2050. As passenger levels grow, land use efficiency is expected to grow as well, so a large share of these savings comes from avoided travel among community members who may not be transit passengers. Even with the gradual uptake of personal electric vehicles and cleaner electricity sources, transit provides significant savings to communities into the future.

Transit Vehicle Emissions Fall Significantly

The combined scenario of electrification, zero-carbon electricity, and increased ridership eliminates 83% of transit vehicle emissions by 2050 even as ridership triples. Emissions from transit vehicles fall from just over 12 MMT CO_2e in 2018 to 2 MMT CO_2e in 2050 (see Figure 12). The scenario elements creating these changes are explained further in the following.

Strong Electrification of Transit

As a first future hypothetical, the scenarios apply a significant uptick in electrification to the base case—the assumptions include 50% of buses becoming electric by 2030, 80% of buses becoming electric by 2050, and rail becoming fully electric by 2050. This would reduce the direct and indirect emissions associated with transit vehicles from 10 MMT CO_2e in 2018 to just over 6 MMT CO_2e in 2030 and about 2 MMT CO_2e in 2050.

Clean Power

The second hypothetical assumption made in the scenarios is that all electricity used for public transportation vehicles comes from zero GHG emissions sources. This change is applied on top of the strong electrification assumption. With clean power, the two steps together would reduce the direct and indirect emissions associated with transit vehicles from 10 MMT CO_2e in 2018 to 4 MMT CO_2e in 2030 and just over 1 MMT CO_2e in 2050.

The electrification and clean power scenario elements can also be considered proxies for other zero-carbon fuels and technologies, including the adoption of fuel cells using zero-carbon hydrogen.

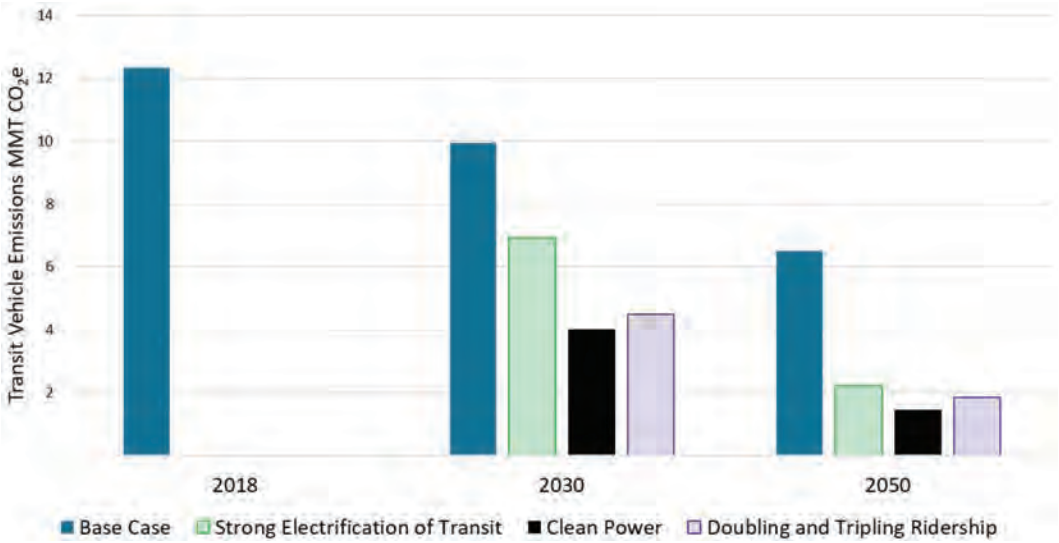

Figure 12. Transit vehicle direct and indirect GHG emissions, 2030 and 2050 scenarios.

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Doubling and Tripling Ridership

Increasing ridership is the strongest way to increase public transportation's GHG impacts in communities (Figure 11). Increasing ridership will require additional transit service, which can increase transit vehicle GHG emissions, but this is more than offset by the GHG savings of passengers who avoid personal vehicle use and the larger land use impacts of transit. In this scenario, ridership is doubled over 2018 levels by 2030 and tripled by 2050; at the same time, average occupancy rises above 50% so that some of the additional ridership is absorbed on base-case transit vehicle trips. These assumptions are applied on top of the strong electrification and clean power assumptions. This assumption increases transit vehicle emissions slightly, but that is more than offset by the GHG benefits generated.

Scenario Tool

The spreadsheet tool produced along with this report allows users to apply these scenarios to 2018 data for individual transit systems to give transit agency staff, decision makers, and researchers a sense of the potential scale of the actions described here.

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CHAPTER 4

Conclusions and Suggested Research

Public Transportation Is Essential to Climate Action

Public transit has been a major source of GHG reductions in the United States, and that continued in 2018. The 63 MMT CO_2e that public transportation saved in 2018 is a value larger than the entire national emissions of 111 individual countries. New Zealand, Finland, and Singapore each emitted 63 MMT CO_2e across their entire economies in 2016 (ClimateWatch n.d.).

Public Transportation's Climate Actions

The numerous efforts that transit agencies have made to improve efficiency and tackle their GHG emissions have come together with technology advances and other forces in the past decade to make public transportation an even cleaner mode of travel than it was found to be in previous national assessments of its climate impact.

Transit Emissions Reduction Exceeds Other Modes. Transit GHG emissions reductions have kept pace with fuel efficiency improvements in gasoline personal vehicles on the road. Rail modes are more carbon efficient than personal electric cars and are becoming even lower emissions as our electricity decarbonizes nationwide. The latest battery electric buses rival electric cars in their per-passenger emissions profile as well.

Transit Enhances Community Efficiency. Public transportation helps make communities more efficient. The land use efficiency research in this report shows large, statistically significant reductions in VMT in communities with transit above and beyond the personal auto trips avoided by transit riders.

Transit Is Expanding Its Climate Action Strategies. Transit agencies are taking a wide variety of climate actions, from leveraging biofuels and hybrid technologies to improving operations and operating conditions for transit vehicles to reduce fuel use while improving reliability and service. Some transit agencies are reaching beyond their usual sphere of activity to install renewable power generation on transit agency property as a means of managing their GHG impacts. Transit agencies are also supporting efforts toward decarbonization of communities by supporting and pursuing equitable transit-oriented housing development to help households live efficiently and affordably.

All of this is good news for communities seeking to take action to address climate change. Public transportation is already creating positive climate impacts in communities in which it operates, and it has the potential to do even more.

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Public Transportation's Potential for Scalable Climate Solutions

Economies of scale may make it possible for public transit to electrify and adopt clean power faster than the millions of individual drivers it would take to have the same impact on U.S. transportation emissions. Furthermore, public transportation can do this while creating cost savings for residents as it helps households avoid a second auto purchase or reduce reliance on taxis and ridehailing. The access to essential jobs and services that public transportation provides is a critical part of a community's overall resiliency.

The ridership and service changes that occurred in 2020 due to the COVID-19 pandemic have disrupted business-as-usual transportation in many communities, and the GHG impacts of this remain to be seen, but climate action investments have the potential to make a post-pandemic era one of lower-carbon transportation that supports equitable, healthy, and resilient communities. Public transportation is an essential element to achieving these outcomes.

As transit agencies look to technology transformations to deepen their climate benefits, many will need funding and financing to make that change possible. The up-front cost to electrify a fleet, including infrastructure, maintenance facilities, training, and vehicles, is significant and needs to be addressed in order to generate the many benefits electrification can bring to communities of all sizes.

Applying These GHG Findings

The GHG analysis presented here is meant to be a resource for transit agencies, decision makers, communities, and other public transportation and sustainability stakeholders. This information can be used to guide decision making toward lower-carbon fuels, technologies, and operations improvements, as well as demonstrating the importance of transit ridership and occupancy as a climate solution. The analysis in this research project is also meant to provide the information necessary to communicate public transportation's important role as a climate solution. To those ends, tools for communication and ideation have been created as part of this project. These supplementary materials can be obtained at www.TRB.org by searching for "*TCRP Research Report 226*":

1. **Three one-page factsheets** that present key findings regarding transit as a climate solution.
2. **A PowerPoint slide deck** summarizing these findings and the research they are based on with the infographics and charts used in this document. This tool also includes templates for transit agencies to add their own data for climate communications. These slides and infographics can be used by transit stakeholders. The key findings of this analysis are provided in several formats to enable use on social media and websites.
3. **A simple spreadsheet tool** that provides this study's 2018 GHG impact findings by transit agency and allows the user to apply several of the climate action scenarios to see how their transit agency's 2018 GHG impacts change with electrification, clean power, and ridership increases.

Suggested Research

Inclusion of GHGs in NTD

Tracking GHG emissions impacts regularly is important to measuring progress and to continuous learning. Transit agencies report their activity data to the NTD each year, so the GHG calculations in this report could be repeated annually as part of the database compilation process, which would provide transit agencies and communities necessary data to manage

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climate impacts. There is interest in this type of standardization and economy of scale among transit agency staff members and decision makers.

Overall, the NTD energy data provide a robust basis for calculating the GHG emissions associated with transit vehicles to a high degree of certainty on a national basis. However, parts of the data structure are not aligned with GHG accounting needs, as indicated in Appendix A. The energy data reported to NTD also exclude some newer fuel types, such as renewable diesel, which may be reported as biodiesel, diesel, or other. Furthermore, there are a small number of outlier values and data gaps when one looks at the data on an agency-by-agency basis that should be corrected.

An assessment of NTD reporting guidelines for the purpose of supporting GHG calculations would enable the relatively limited changes that would be necessary to make GHG calculations a regular part of NTD reporting. Metrics suggested for such reporting include GHG emissions per passenger mile traveled, GHG emissions per vehicle mile, average vehicle occupancy, and net transit GHG impacts including transportation efficiency and land use efficiency. The APTA *2019 Public Transportation Fact Book* (APTA 2019) is another potential platform for this information.

Additional fuel and technology life-cycle information matched specifically to transit operational needs and procurement choices would also support low-carbon decision making.

Documenting Other Transit GHG Sources and Savings Opportunities

This study examined the GHG emissions of transit vehicles based on fuel use and vehicle miles. The full GHG footprint of transit agencies includes other emissions sources, such as the energy use of facilities and non-transit vehicles. These are typically much smaller than vehicle GHG emissions; examination of five past transit agency GHG inventories found revenue transit vehicles represented 65% to 95% of transit agency GHG emissions (McGraw et al. 2010, Southworth et al. 2011), but facilities and other emissions sources may become larger shares of the total impact of transit agencies as service vehicle GHGs decrease. Further documentation of these activities and best practices in reducing their emissions would help transit agencies and communities prioritize climate action investments.

This research would also be an opportunity to document transit agency clean power investments and purchases to better understand the scale of public transportation's role as a zero-carbon–energy producer and consumer. Operational and infrastructure assessments should also include information on public transportation's vulnerability to climate change and opportunities to harden assets to the increased flooding, fire, intense storms, and extreme heat we are now facing.

Localizing Mode Shift Data

The research presented here provides an assessment of the national GHG impacts of transit using best-practice GHG accounting techniques and activity data. The APTA data compilation used to calculate the mode shift factor is based on real-world passenger surveys and provides an up-to-date look at transportation options, including ridehailing. However, transit agencies would like more granular data of this type. Passenger surveys are time consuming and costly for smaller transit agencies. Using the national compilation of transit survey data along with place-based ridership and other travel information, such as from anonymized cell-phone data, it would be possible to build a national model of passenger mode shift preferences that

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would provide transit agencies more granular information on this issue. This would be valuable for GHG accounting reasons and could inform transit agency operations, partnerships, and investments.

Further Unpacking Location Efficiency Impacts

The transit multiplier modeling for this study presents a wealth of findings and opportunities for further research. This could include a comparative look at model outputs in regions to better identify the causal forces of transit's impacts on personal travel in the community; it is important to pay attention to causal effects on VMT, beyond correlation, when designing climate action.

Land use patterns take time to develop, so the authors expect that areas with long-established transit and location-efficient land use patterns may see different impacts from areas with more recent changes. The authors also expect that regional variation may play a role. A more granular approach that looks at station-based ridership would be valuable but challenging to undertake on a national scale given the limits of existing ridership data (Pollack et al. 2015). Developing a method for mode-specific transit multipliers, though difficult to differentiate in areas with multiple modes overlapping spatially, would also be of use for transit service expansion decisions. Further unpacking transit's location efficiency impacts would help shape climate action and target land use innovations that could help decarbonize communities while making them more transportation cost effective and healthy.

Overall, in undertaking this research, the authors found a widespread interest in public transportation's role as part of the essential infrastructure of communities addressing and responding to climate change. Continued research and action to identify and grow transit's substantial climate benefits is of great importance to communities around the United States and the world.

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APPENDIX A

GHG Analysis Methodology

To allow readers to walk through the analytical steps used, this appendix provides details of the public transportation GHG analysis summarized in the main body of the report, including calculation formulas and reference tables for the GHG emissions factors used in the assessment.

Vehicle Typology

The NTD provides transit data by mode names and vehicle types. For the purposes of this study, these have been summarized into six mode types: bus, commuter rail, ferry, heavy rail, light rail, and van (see Table A-1).

Calculating Emissions from Transit Vehicle Activity

The GHG calculations are activity × emissions factor by transit agency, mode, and fuel type, as described here:

- CO_2
  - **Compressed natural gas, diesel, gasoline, hydrogen, liquefied natural gas, liquefied petroleum gas:** Gallons of fuel use × kg CO_2 per gallon = kg CO_2
  - **Electricity:** kWh of electricity use × kg CO_2 per kWh = kg CO_2
  - **Biofuels (biodiesel and ethanol):** Gallons of fuel use × kg CO_2(b) = kg CO_2(b); biogenic CO_2 reported separately
- CH_4 and N_2O
  - **Hydrogen; rail and ferry diesel and biodiesel:** Gallons of fuel use × kg GHG per gallon × GWP = kg GHG CO_2e
  - **Electricity:** kWh of electricity use × kg GHG per kWh × GWP = kg GHG CO_2e
  - **Other bus and van fuels:** Miles of vehicle travel × kg GHG per mile × GWP = kg GHG CO_2e. (In cases where miles of vehicle travel by fuel were unreported, gallons of fuel use × kg GHG per gallon × GWP = kg GHG CO_2e was substituted.)
    - CNG
    - Diesel fuel
    - Ethanol
    - Motor gasoline
    - LNG
    - LPG
    - Biodiesel

Upstream ("well-to-pump") CO_2e calculated separately based on fuel use.

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Table A-1. Mode type typology and NTD mode name and vehicle type.

NTD Mode	NTD Mode Name	Mode Type
MB	Bus	Bus
RB	Bus Rapid Transit	Bus
CB	Commuter Bus	Bus
IB	Intercity Bus (Rural Module)	Bus
PB	Publico	Bus
TB	Trolleybus	Bus
AR	Alaska Railroad	Commuter Rail
CR	Commuter Rail	Commuter Rail
YR	Hybrid Rail	Commuter Rail
FB	Ferryboat	Ferry
HR	Heavy Rail	Heavy Rail
CC	Cable Car	Light Rail
IP	Inclined Plane	Light Rail
LR	Light Rail	Light Rail
MG	Monorail and Automated Guideway	Light Rail
SR	Streetcar Rail	Light Rail
DR	Demand Response	Van
JT	Jitney	Van
VP	Vanpool	Van

NTD Vehicle Type	Mode Type
Over-the-Road Bus	Bus
Articulated Bus	Bus
Bus	Bus
School Bus	Bus
Double Decker Bus	Bus
Trolleybus	Bus
Commuter Rail Passenger Coach	Commuter Rail
Commuter Rail Self-Propelled Passenger Car	Commuter Rail
Commuter Rail Locomotive	Commuter Rail
Ferryboat	Ferry
Heavy Rail Passenger Car	Heavy Rail
Vintage Trolley	Light Rail
Inclined Plane Vehicle	Light Rail
Monorail Vehicle	Light Rail
Streetcar Rail	Light Rail
Cable Car	Light Rail
Aerial Tramway	Light Rail
Light Rail Vehicle	Light Rail
Automated Guideway Vehicle	Light Rail
Minivan	Van
Automobile	Van
Van	Van
Cutaway	Van
Other	Van
Sports Utility Vehicle	Van

Activity Data

The activity data used to calculate emissions from transit revenue vehicles are the energy use data and vehicle mileage data reported in the NTD. The most recent data year at the time of the analysis was 2018. NTD data for 2019 were released in November 2020, after the completion of the analysis in this report. These data show a similar overall level of transit ridership to that of 2018, indicating that the 2018 analysis is generally comparable to 2019. There were 54.4 billion passenger miles traveled over 9.9 billion passenger trips in 2019, and 54 billion passenger miles over 9.9 billion passenger trips in 2018 (FTA 2020a).

Table A-2 presents a summary of the fuel use activity data used for the analysis. Table A-3 summarizes vehicle mile data by mode and fuel. To better match fuel use data and represent the full range of transit vehicle activity, total vehicle miles were used rather than revenue vehicle miles.

Energy use data were only reported by "full reporters" to the NTD; as such, smaller transit agencies are left out of this activity dataset. Energy, vehicle, and passenger data from 523 "full reporter" transit agencies (at least 30 vehicles and/or fixed guideway or high intensity busway) are included in this analysis.

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Table A-2. Public transportation fuel use by vehicle type, 2018.

Fuel Use (Gallons and kWh)							
	Bus	Commuter Rail	Ferry	Heavy Rail	Light Rail	Van	Total
Biodiesel (gallons)	46,590,869	143,818	1,100,743	–	–	1,236,833	49,072,263
Compressed Natural Gas (gallons)	173,772,949	–	–	–	–	8,286,190	182,059,139
Diesel Fuel (gallons)	372,781,007	101,488,109	41,233,792	–	–	16,395,644	531,898,552
Electric Battery (kWh)	9,895,626	–	–	–	–	812	9,896,438
Electric Propulsion (kWh)	71,459,861	1,733,406,171	–	3,873,732,974	1,029,184,381	–	6,707,783,387
Ethanol (gallons)	–	–	–	–	–	46,850	46,850
Gasoline (gallons)	9,972,623	–	–	–	–	99,372,365	109,344,988
Hydrogen (gallons)	137,559	–	–	–	–	–	137,559
Liquefied Natural Gas (gallons)	2,754,682	–	–	–	–	528,447	3,283,129
Liquefied Petroleum Gas (gallons)	2,364,130	–	–	–	–	7,626,854	9,990,984

Table A-3. Public transportation vehicle miles by fuel type and vehicle type, 2018.

Vehicle Miles (includes passenger car miles for rail)							
	Bus	Commuter Rail	Ferry	Heavy Rail	Light Rail	Van	Total
Biodiesel	189,697,235	230,681	101,738	–	–	13,845,889	203,875,543
Compressed Natural Gas	517,119,149	–	–	–	–	60,242,887	577,362,036
Diesel Fuel	1,518,684,875	201,594,805	4,485,677	–	–	130,312,075	1,855,077,431
Electric Battery	4,230,386	–	–	–	–	5,236	4,235,622
Electric Propulsion	10,727,845	211,215,029	–	709,171,041	132,959,517	–	1,064,073,432
Ethanol	–	–	–	–	–	515,536	515,536
Gasoline	24,243,615	–	–	–	–	905,167,673	929,411,288
Hydrogen	729,080	–	–	–	–	–	729,080
Liquefied Natural Gas	3,166,647	–	–	–	–	2,453,751	5,620,398
Liquefied Petroleum Gas	3,018,975	–	–	–	–	39,746,015	42,764,990
Total	2,271,617,806	413,040,515	4,587,415	709,171,041	132,959,517	1,152,289,062	4,683,665,356

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The authors used service and vehicle inventory data as reported by reduced reporters in the NTD to estimate the energy use and emissions of those systems based on the performance indicators calculated from the full reporters. Energy use and passenger miles were estimated for 384 reduced and other reporter transit agencies.

The NTD reporting structure required several data changes to fit GHG accounting needs:

- In cases where more than one fuel type was associated with a vehicle (such as a flex-fuel vehicle using both gasoline and compressed natural gas), the fuel estimation for reduced reporters was allocated on a 60% fossil fuel, 40% alternative fuel basis.
- In cases where the fuels used were fossil fuel and electric, the fuel estimation was allocated at 80% fossil fuel and 20% electric.
- Vehicle mileage for multi-fuel vehicles was allocated using these same proportions. The mileage of vehicles with more than one fuel was approximately 0.3% of total vehicle miles.
- NTD does not separate biodiesel bus miles from diesel bus miles, so those mileages were allocated proportional to fuel use. The resulting estimated biodiesel vehicle mileage was 4% of total vehicle miles.
- In cases where fuel usage was reported as "other" or with no type, it was allocated by type according to vehicle technology information reported by the agency or other indicators of likely fuel type. Vehicles traveling approximately 4% of total vehicle miles, largely commuter rail vehicles, were included in these estimations.

The net result was a database of fuel use and vehicle mileage by vehicle type among 907 transit agencies. The reduced and other reporter agencies are 42% of the agencies in this dataset, but they include just 5% of the transit vehicles (7,172 of 139,689 total transit vehicles) and 4% of the transit vehicle miles in the study (164,634,348 of 4.7 billion miles).

The dataset in this report excludes 2,035 rural, reduced asset, and other transit agencies that did not report enough data to NTD to enable estimation of vehicle activity by fuel. The included activity data analyzed in this report from full reporters and reduced reporter estimations equate to 82% of 2018 miles in the APTA *Public Transportation Fact Book*, based on which the excluded activity is primarily bus and van transit (APTA 2019).

A close examination of vehicle-level activity reporting by agency and fuel finds some irregularities that could not easily be addressed within the scope of this project. For example, the vehicle mileage by fuel reporting does not always match agency total mileage by mode. Also, NTD documentation suggests that biodiesel be reported as diesel, so there is likely to be some mixed reporting of those fuels. The NTD does not report newer or less common fuels, such as renewable diesel, so those may be mixed in with biodiesel or other fuels. At a nationwide scale, none of these variances are large enough to have a meaningful impact the overall results of the study. The spreadsheet tool that accompanies this project includes transit-agency–level data.

Emissions Factors

The GHG analysis used commonly accepted emissions factors for the transportation fuels listed previously, as follows (see also Table A-4):

- The CO_2 values for fuels other than electricity were sourced from "Emissions Factors for Greenhouse Gas Inventories" (U.S. EPA 2020b). This is a well-documented source of up-to-date data that aligns with emissions factors in other major reporting programs. Another straightforward source for emissions factors in common measurement units that can be used as a reference is the Climate Registry's "2020 Default Emissions Factors" document (TCR 2020).
- EPA emissions factors (U.S. EPA 2020b) were also used for CH_4 and N_2O emissions.

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Table A-4. Direct and indirect emissions factors.

Emissions Factors	Per Energy Unit				
All Vehicles	**CO_2**	**Units**	**CH_4 CO_2e**	**N_2O CO_2e**	**Units**
CNG	7.32	kg/gallon of diesel equivalent	0.00388	0.00356	kg/gallon of diesel equivalent
Diesel Fuel	10.21	kg/gallon	0.01148	0.02120	kg/gallon
Electricity, National Average	0.43	kg/kWh	0.00108	0.00144	kg/kWh
Electricity, Lowest Subregion	0.11	kg/kWh	0.00023	0.00024	kg/kWh
Electricity, Highest Subregion	0.76	kg/kWh	0.00235	0.00325	kg/kWh
Motor Gasoline	8.78	kg/gallon	0.01064	0.02120	kg/gallon
Hydrogen (Wang et al. 2020)	14.48	kg/gallon of diesel equivalent	1.49562	0.08684	kg/gallon of diesel equivalent
LNG	4.50	kg/gallon	0.00388	0.00356	kg/gallon
LPG	5.68	kg/gallon	0.00784	0.01590	kg/gallon
	CO_2 (b)	**Units**	**CH_4 CO_2e**	**N_2O CO_2e**	**Units**
Biodiesel	9.45	kg/gallon	0.00392	0.00265	kg/gallon
Ethanol	5.75	kg/gallon	0.00252	0.00265	kg/gallon
			By Vehicle Type		
Buses (Also Used for Vans)			**CH_4 CO_2e**	**N_2O CO_2e**	**Units**
CNG			0.28000	0.00027	kg/mile
Diesel Fuel			0.00027	0.01142	kg/mile
Electricity National Average			0.00108	0.00144	kg/kWh
Motor Gasoline			0.00026	0.00087	kg/mile
LNG			0.28000	0.00027	kg/mile
LPG			0.00095	0.00451	kg/mile
Biodiesel			0.00025	0.01140	kg/mile
Ethanol			0.00062	0.00848	kg/mile
Locomotives					
Diesel Fuel			0.02240	0.06890	kg/gallon
Electricity National Average			0.00108	0.00144	kg/kWh
Ships and Boats					
Diesel			0.00868	0.13250	kg/gallon
Personal Vehicles					
Passenger Car			0.00025	0.00212	kg/mile
Light-Duty Truck			0.00034	0.00265	kg/mile
All Light-Duty Vehicles 2018			0.00027	0.00224	kg/mile
Electricity National Average			0.00108	0.00144	kg/kWh

Source: U.S. EPA 2020a, U.S. EPA 2020b.

- Intergovernmental Panel on Climate Change Fifth Assessment Report (AR5) 100-year GWPs for CH_4 (28) and N_2O (265) were used to convert those GHGs to CO_2e (Myhre et al. 2013).
- Upstream, "well-to-pump" emissions factors from Argonne National Laboratory's GREET 2020 model, using high heating values, were used to calculate the upstream emissions associated with transit vehicle operations as a separate figure from direct emissions (see Table A-5) (Wang et al. 2020).
- For electricity use, U.S. EPA's eGRID 2018 Summary Tables were used to assign CO_2, CH_4, and N_2O electricity emissions factors to each transit agency by matching the transit agency headquarters zip code in NTD to the corresponding eGRID Subregion (U.S. EPA 2020a). An estimate for Puerto Rico was developed using local power production information, and

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Table A-5. Upstream (well-to-pump) emissions factors.

Fuel	GHG Emissions CO_2e	Units	Fuel Description
Biodiesel	3.70	kg per gallon	Biodiesel Production from Soybeans
CNG	2.16	kg per gallon of diesel equivalent	Compressed Natural Gas from North American Natural Gas
Diesel Fuel	2.17	kg per gallon	U.S. Low-Sulfur Diesel
Electricity National Average	0.02	kg per kWh	Electricity Distributed net of Electricity Not Distributed (the same as electricity transmission and distribution (T&D) losses in eGRID)
Ethanol	4.08	kg per gallon	Average Ethanol Produced in the U.S. (at the Refueling Station)
Hydrogen	Life-cycle emissions factor used as indirect emissions factor, so no upstream emissions assumed		
LNG	1.62	kg per gallon	Liquefied Natural Gas as a Transportation Fuel from North American Natural Gas
LPG	1.28	kg per gallon	Liquefied Petroleum Gas from Natural Gas and Petroleum
Motor Gasoline	2.60	kg per gallon	Reformulated Gasoline (E10) Blending and Transportation to Refueling Station

Source: Wang et al. 2020.

that estimate was applied to the U.S. Virgin Islands as well [Center for Climate Strategies (CCS) 2014]. Table A-4 shows the national high, low, and average electricity emissions factors for reference, but the full set of eGRID subregions were used in the analysis.
  - Note that some transit agencies are producing renewable energy or sourcing grid-connected renewable electricity that was cleaner than their grid subregion. There was no national data source for those contractual arrangements so they are not included in this report. However, eGRID includes utility-scale grid-connected renewables in its regional averages.
- GREET (Wang et al. 2020) life-cycle emissions factors for compressed gaseous hydrogen from natural gas without CO_2 sequestration were applied to hydrogen fuel use. For the purposes of this report, the resulting emissions are classified as indirect rather than upstream to allow a more apples-to-apples comparison to indirect electricity emissions.

Motor gasoline in the United States is typically oxygenated to some degree with ethanol. This is often labeled E10 or 10% ethanol, but the actual makeup is variable by season, location, distributor, and more, and customers rarely receive this information. For this reason, most GHG accounting protocols do not require accounting of this share of motor gasoline CO_2 separately, and the authors have not done so in this report (TCR 2019).

There is ambiguity in the NTD about fuel units that adds a small amount of uncertainty to the GHG calculations. Transit agencies that use compressed natural gas are encouraged to report that fuel in either gallons of gasoline equivalent [114,000 British Thermal Units (BTU)] or gallons of diesel equivalent (138,000 BTU), but there is no notation in the publicly accessible data indicating which unit has been used. For the purposes of this study, the compressed natural gas emissions factors were converted into gallons of diesel equivalent. Similar questions arise about all of the fuels reported in gallon equivalents (hydrogen, liquefied natural gas, and liquefied petroleum gas)—the emissions factor source may not be using the same gallon unit as the agency reporters. These fuels make up just 15% of the total emissions results, so this ambiguity of units does not have a significant impact on the study findings at a broad scale.

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Transportation Efficiency: Calculating Avoided Emissions from Transit Passenger Travel

The net GHG benefits of transit as calculated for this project include the avoided GHG emissions of private automobile use by transit passengers, also called transportation efficiency. The NTD-reported passenger mile data were the basis for this analysis using the calculations described here:

- Avoided CO_2
  - Passenger miles × **mode shift factor** (0.329) = avoided vehicle miles
  - Avoided vehicle miles/miles per gallon (22.5 2018 FHWA on-road light-duty vehicles) = avoided gallons of fuel
  - Gallons of fuel use × kg CO_2 per gallon = kg CO_2
- Avoided CH_4 and N_2O
  - Avoided miles of vehicle travel × kg GHG per mile × GWP = kg GHG CO_2e
- Upstream GHGs (well-to-pump)
  - Calculated using GREET emissions factors

Mode Shift Factor

APTA's 2017 *Who Rides Public Transportation* provided a summary of 69 transit agency surveys, representing the choices of 233,925 passengers (APTA 2017). An update to APTA's 2017 dataset adds four newer transit agency surveys (APTA 2020). These newer surveys now allow transit passengers to indicate that they would otherwise use ridehailing services such as Uber or Lyft.

Adjusting for the "other transit" category, the vehicle alternatives passengers indicated in the newest APTA summary are 12% ridehailing, 14% drive alone, 10% carpool (which is divided by 2.5 passengers per carpool for this analysis), and 3% taxis (APTA 2020). The result is that 32.9% of transit passenger miles would otherwise be replaced by personal vehicle miles.

The term "personal vehicle" is used to indicate automobiles and light trucks and includes ridehailing and taxi vehicles for hire. The average personal vehicle on the road in 2018 had a fuel economy of 22.5 mpg.

Mode Shift Factor as Applied in Previous Studies

Previous analysis of transit's GHG impact approached passenger GHG savings differently. A study using 2005 NTD data apportioned **every** passenger mile to an avoided vehicle trip and used vehicle occupancy to estimate total VMT savings (1.08 occupancy for work trips and 1.90 occupancy for other trips) (Davis and Hale 2007). The result was an effective mode shift factor of 0.745, or about 75% of transit passenger miles replaced by personal vehicle miles. A lower mode shift factor accounting for trips that would have otherwise been taken by zero-carbon modes, including walking, biking, or no trip, such as are used here, is a better match to real-world activity. However, there is significant local variability that any national value leaves out, and more granular data should be developed.

As mentioned previously, this study uses the latest APTA survey data to calculate a mode shift factor of 0.329, meaning that 33% of transit passenger miles would otherwise be replaced by personal vehicle miles. APTA's "Recommended Practices: Quantifying Greenhouse Gas Emissions from Transit" (APTA 2018), uses older APTA 2017 survey data and finds a slightly lower mode shift factor (0.302) for transit systems serving areas with 1 million residents or more, but a higher factor (0.508) for transit systems serving less than 1 million people. These data show that in smaller communities, fewer transit passengers indicate that they would otherwise walk, and more indicate that they would otherwise get a ride from someone else.

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Table A-6. Personal vehicle GHG emissions, 2018.

	Personal Gasoline Vehicle	Personal Electric Vehicle
Fuel Economy (FHWA 2019a)	22.5 mpg	30 kWh per 100 miles
Direct and Indirect GHG Emissions per Vehicle Mile (kg CO_2e)	0.39	0.03 to 0.23
Upstream GHG Emissions per Vehicle Mile (kg CO_2e)	0.12	0.01
Total GHG Emissions per Vehicle Mile (kg CO_2e)	0.51	0.04 to 0.24
2018 Average Miles Driven per Vehicle in U.S. (FHWA 2019a)	11,556	11,556
Average 2018 U.S. Personal Vehicle GHG Footprint (MT CO_2e)	5.9	0.5 to 2.7

Applying the older mode shift data used in the APTA Recommended Practice to the 2018 NTD data results in only a small difference nationally (4%) from the analysis in this study, but individual agencies analyzing their GHGs should use a locally appropriate factor. A breakout of the newest survey data by transit service area population was not available for this study, and the authors concluded that there was value to using the updated numbers because ridehailing is such a significant new transportation choice; however, further research into this factor would be beneficial for future analyses.

Personal Vehicle Emissions

The emissions savings from avoided personal vehicle use are based on a national average fuel economy for automobiles and light trucks of 22.5 mpg (FHWA 2019a) and the GHG emissions factors for motor gasoline. Table A-6 shows that the GHG footprint for a typical gasoline-powered personal vehicle in 2018 was 0.51 kg CO_2e per mile, or 5.9 MT CO_2e at the average annual driving distance of 11,556 miles (FHWA 2019a).

Electric vehicles made up approximately 0.4% of all light-duty vehicles in 2018 (EEI 2019 and FHWA 2019a). The transportation efficiency calculations do not include electric personal vehicles because of a lack of data about the location of electric vehicles and their limited prevalence in 2018; however, in the future this will become a more important factor, and data about electric vehicle adoption by urbanized area should be cultivated. Table A-6 shows that a personal electric vehicle driven 11,556 miles in 2018 would have contributed 0.5 to 2.7 MT CO_2e emissions, depending on the emissions factor associated with the electricity powering the vehicle. Chapter 3 discusses the GHG impacts of personal electric vehicles on the personal vehicle emissions savings on a national level for 2018.

Emissions from first- and last-mile or transit access by passengers are not included in this study due to data constraints, but transit access modes are an important part of transit's overall contribution to community GHG solutions and should be considered as part of climate action planning.

Land Use Efficiency: Calculating Avoided Emissions from Community Travel

The GHG emissions saved by the broader impact of transit on VMT in the community, such as through shorter trips and fewer personal vehicle trips (also called indirect effect), are a part of the net GHG benefits of transit in this study. NTD-reported passenger mile data were the basis for this analysis using the calculations described here:

- Avoided CO_2
  - Passenger miles × mode shift factor (0.329) = avoided passenger vehicle miles
  - [(Avoided passenger vehicle miles × **transit multiplier**) − avoided passenger miles] = avoided community vehicle miles

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  - Avoided community vehicle miles/miles per gallon (22.5 2018 FHWA on-road light-duty vehicles) = avoided gallons of fuel
  - Gallons of fuel use × kg CO_2 per gallon = kg CO_2
- Avoided CH_4 and N_2O
  - Avoided community vehicle miles × kg GHG per mile × GWP = kg GHG CO_2e
- Upstream GHGs (well-to-pump)
  - Calculated using GREET emissions factors

Transit Multiplier

The transit multiplier is the total VMT reduction associated with transit, including both transportation efficiency and land use efficiency VMT savings divided by the transportation efficiency VMT savings to create a multiplier. The multiplier allowed the researchers to take research findings about transit's impact on VMT in 28 communities and apply them to every transit agency in this study in a regionally specific way.

$$\text{Transit multiplier} = \frac{(\text{transportation efficiency VMT}) + (\text{land use efficiency VMT})}{(\text{transportation efficiency VMT})}$$

- **Transportation Efficiency:** VMT reduction of transit passengers (also called transit direct effect on VMT)
- **Land Use Efficiency:** VMT reduction in the community. Even residents who do not ride transit themselves save VMT, such as through shorter trips and fewer driving trips (also called transit indirect effect on VMT).

The transit multipliers for this study were developed using a multilevel structural equation model and a database of household travel survey data in 28 regions matched with socioeconomic, built environment, and regional characteristics. The model found that the effect of transit in the community is much larger than the avoided auto use of transit passengers alone, but rather changes in the built environment in communities that are well served by transit create VMT savings several times larger than that passenger impact. The modeling found a range of multipliers from 6.1 to 9.5 in the 28 regions. The average transit multiplier, using the combined data of the 28 regions, was 7.43 (see Appendix B).

The modeling generated a set of equations that were used to estimate the transit multiplier for every transit agency in this study based on transit passenger miles per capita, which was calculated as NTD passenger miles divided by the sum of urbanized area (UZA) populations for all of the UZAs in the transit agency service area. The transit multipliers were calculated using the following formulas based on coefficients developed through the model:

Transportation efficiency VMT:

$$= [0.001 \times (-2.882 + (0.002 \times (\text{transit passenger miles per capita} - 130.05)))]$$
$$+ [0.0017 \times 2.871 \times (-2.882 + (0.002 \times (\text{transit passenger miles per capita} - 130.05)))]$$

Land Use Efficiency VMT:

$$= [0.093 \times (-0.098 + (0.0004 \times (\text{transit passenger miles per capita} - 130.05)))]$$
$$+ [-0.091 + (-0.0001 \times (\text{transit passenger miles per capita} - 130.05))]$$

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Personal Vehicle Emissions

The GHG emissions associated with avoided personal vehicle use in the community are calculated based on avoided VMT using the same method described in the Personal Vehicle Emissions subsection of the Transportation Efficiency: Calculating Avoided Emissions from Transit Passenger Travel section of this appendix.

Previous Research on Land Use Efficiency

The previously mentioned study of 2005 transit impacts found that transit led to emissions reductions of 37 MMT CO_2 annually in the United States, including a land use multiplier—transit's indirect impact on household VMT—of approximately 2× (Bailey et al. 2008). This means that for every personal vehicle mile saved by a transit rider, nearly two more vehicle miles are saved in the community. More recent analysis of Portland, Oregon, has shown the transit land-use multiplier to be 3× (Ewing and Hamidi 2014, Gallivan et al. 2015).

Table A-7 provides a summary of land use multiplier studies and highlights the range of estimates in this area of research. The range of 1.4 to 9 in the research comes both from a range of research approaches and real-world variable impact across places. This is still a new area of study, and there have been inconsistencies in the scope of the studies, in the land use measures that have been used, and with the survey methods and statistical modeling techniques that have been used.

Some studies were national in scope (e.g., Neff 1996); others focused on particular metropolitan areas or cities. Some relied on data aggregated to geographic units; others used individual- or household-level data.

Holtzclaw (2000) used a straightforward VMT and transit passenger mile per capita comparison between San Francisco and less transit-oriented suburbs. Bailey et al. (2008) and several later studies used a structural equation model statistical approach that controlled for characteristics of the area, including land use, transportation systems, and demographics.

Several issues arise when applying the existing land-use multiplier literature to NTD transit activity data. First, what is being multiplied? Many study findings are described in terms of total

Table A-7. Summary of land use multiplier studies.

Study	Study Areas	Land Use Multiplier
Pushkarev and Zupan (1982)	U.S. metro areas with at least 2 million population	4
Neff (1996)	U.S. urbanized areas	5.4–7.5
Newman and Kenworthy (1999)	32 global cities	5-7
Holtzclaw (2000)	Matched pairs in the San Francisco Bay Area	1.4–9
Bailey et al. (2008)	Entire United States	1.9
New York Metropolitan Transportation Authority (2009)	MTA service territory	1.29–6.34
Los Angeles Metropolitan Transportation Authority (2012)	Los Angeles County	5.3
Ewing and Hamidi (2014)	Portland's Westside light-rail transit	3.04
Litman (2020)	130 U.S. cities	4

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VMT saved in the community per transit passenger mile. This combines the direct VMT savings of transit passengers with the broader VMT savings due to transit's impacts on land use. Furthermore, it appears that some of the research includes a vehicle occupancy figure within the multiplier, while in other approaches a vehicle occupancy adjustment is external. Similarly, the mode shift element for transit passengers is incorporated in variable ways.

This study makes explicit the application of the elements of its GHG calculations in the methodology and accompanying materials to help improve transparency in this arena. To avoid confusion with previous research, the authors refer to the value developed in this study as a "transit multiplier." As described in Chapter 2, the transit multiplier when applied to NTD passenger mile data using the formula [((Avoided passenger vehicle miles × transit multiplier) – avoided passenger miles) = avoided community vehicle miles] results in VMT reductions in the range of previous studies.

Exclusion of Congestion Impacts

One of the major changes when the APTA Recommended Practice was updated in 2018 was the exclusion of congestion relief in the GHG benefit calculations (APTA 2018). Previously, a reduction in personal vehicle GHG emissions was calculated based on fewer personal vehicles on the road due to transit ridership resulting in improved efficiency among the remaining personal vehicles. Davis and Hale (2007) found a 3 MMT CO_2 benefit from public transportation due to congestion relief nationally as the transportation efficiency effect enabled more efficient use of private vehicles.

However, there is now a lack of consensus in the literature on transit's congestion impacts. The literature on the subject is well summarized in the APTA Recommended Practice, and inclusion of transit congestion relief as part of a GHG impact assessment is no longer recommended. Therefore, the researchers have excluded congestion from this project as well.

The authors looked at other sources of congestion data and analysis, such as FHWA's *Status of the Nation's Highways, Bridges, and Transit: Conditions and Performance, 23rd Edition* (FHWA 2019b), but have not found a published data source that would allow adequate analysis of the full range of congestion impacts within the scope of this research effort. APTA's Multimodal Urban Mobility Index, under development, provides an innovation in measuring transportation access across modes but does not yet readily translate to national GHG impacts (Economic Development Research Group, Inc. 2018).

Additional Method Resources

Appendix B provides a full technical description of the modeling used to develop the transit multipliers used in this study. In addition, for those looking to calculate transit GHG emissions themselves, the spreadsheet tool published with this report includes several sample GHG impact calculations and the emissions factor tables from this appendix, along with the 2018 GHG impact findings by individual transit agency.

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APPENDIX B

Transit Multiplier Methodology

This appendix provides the full methodology for the model used to develop the transit multiplier for this project. This method and its application in the public transportation GHG analysis are summarized in the body of the report and Appendix A. Appendix B is provided for those who want to explore the details of the transit multiplier structural equation model. The transit multiplier model was developed for this project by Sadegh Sabouri, Ph.D. Candidate in Metropolitan Planning, Policy & Design, College of Architecture and Planning, University of Utah, and Reid Ewing, Ph.D., Professor, City & Metropolitan Planning, Director of the Metropolitan Research Center, University of Utah.

Data and Method

1 – Regional Household Travel Survey and Built Environment Data

This study uses geocoded household travel data to explain household VMT in terms of sociodemographic, built environment, and travel variables. The main criterion for inclusion of regions in this study was data availability. Regions had to offer regional household travel surveys with XY coordinates, so the authors could geocode the precise locations of residences and capture the built environment for households more accurately. It is not easy to assemble databases that meet this criterion because confidentiality concerns mean that metropolitan planning organizations are often unwilling to share XY travel data.

At present, there are consistent datasets for 31 regions. The resulting pooled dataset consists of almost 900,000 trips by 81,573 households (see Table B-1 and Figure B-1). The regions are as diverse as Boston and Portland at one end of the urban form continuum and Houston and Indianapolis at the other. To the researchers' knowledge, this is the largest sample of household travel records ever assembled for such a study outside the National Household Travel Surveys (NHTSs) of 2009 and 2017. And relative to the NHTS, the database for this project provides much larger samples for individual regions and permits the calculation of a wide array of built environmental variables based on the precise location of households. The NHTS provides geocodes (identifies households) only at the census-tract level.

In this project, for each of the 31 regions, the built environment variables (known as 5Ds: density, land use diversity, street design, distance to transit, and destination accessibility) have been computed at the traffic analysis zone (TAZ) level based on these data:

- Population and employment at the block, block group, and TAZ level; from these, activity density can be computed.
- Travel times for auto and transit travel from TAZ to TAZ (so-called travel time skims); from these and TAZ employment data, regional employment accessibility measures for auto and transit can be computed.

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Table B-1. Combined household travel survey dataset from 31 regions of the United States.

Regions	Surveyed Households	Surveyed Trips	Mean of Household Vehicles
Albany, NY	1,309	12,618	2.02
Atlanta, GA	8,729	93,681	2.11
Boston, MA	7,181	86,915	1.64
Burlington, NC	539	5,111	2.24
Charleston, SC	223	2,098	2.04
Dallas, TX	2,824	27,066	2.05
Denver, CO	5,021	55,056	1.94
Detroit, MI	819	14,690	1.49
Eugene, OR	1,592	16,563	1.82
Greensboro, NC	1,768	17,561	2.09
Hampton Roads–Norfolk, VA	1,797	16,495	2.16
Houston, TX	5,233	59,552	2.27
Indianapolis, IN	3,447	37,473	1.89
Kansas City, MO	2,816	31,779	1.84
Madison, WI	128	1,316	2.12
Miami-Dade, FL	1,283	11,580	1.76
Minneapolis–St. Paul, MN	7,439	79,236	1.81
Orlando, FL	775	7,315	2.00
Phoenix, AZ	3,541	37,811	1.92
Portland, OR	4,135	47,551	1.86
Provo-Orem, UT	1,314	19,255	2.08
Richmond, VA	560	5,123	2.13
Rochester, NY	3,393	23,145	1.81
Salem, OR	1,551	16,231	1.82
Salt Lake City, UT	3,034	44,565	2.04
San Antonio, TX	1,547	14,952	1.90
Seattle, WA	4,883	47,877	1.49
Springfield, MA	778	8,456	1.70
Syracuse, NY	592	5,752	1.94
Tampa, FL	2017	17,538	1.79
Winston-Salem, NC	1,305	12,168	2.15
Total	81,573	883,695	1.92

- Parcel-level land-use data with detailed land-use classifications; from these, detailed measures of land use mix can be computed.
- A geographic information system (GIS) layer for street networks and intersections; from these, intersection density and percentage of four-way intersections can be computed.
- A GIS layer for transit stops; from these data, transit stop densities can be computed.

2 – Variables, Conceptual Framework, and Research Design

Variables

The outcome variables are household VMT, activity density, and the number of transit trips per household. There are mediating variables between the percentage of jobs reachable within 30 minutes by transit and household VMT. There are confounding influences, such as household income and household size. The selection of explanatory variables to predict the outcome variables is based on common sense as well as theory. In addition, these are mostly the variables that were used in *TCRP Report 176: Quantifying Transit's Impact on GHG Emissions and Energy Use—The Land Use Component*. (Gallivan et al. 2015)

Different variables are tested for significance as predictors of transit trips, activity density, and VMT, while the final model only includes the independent variables that had an expected

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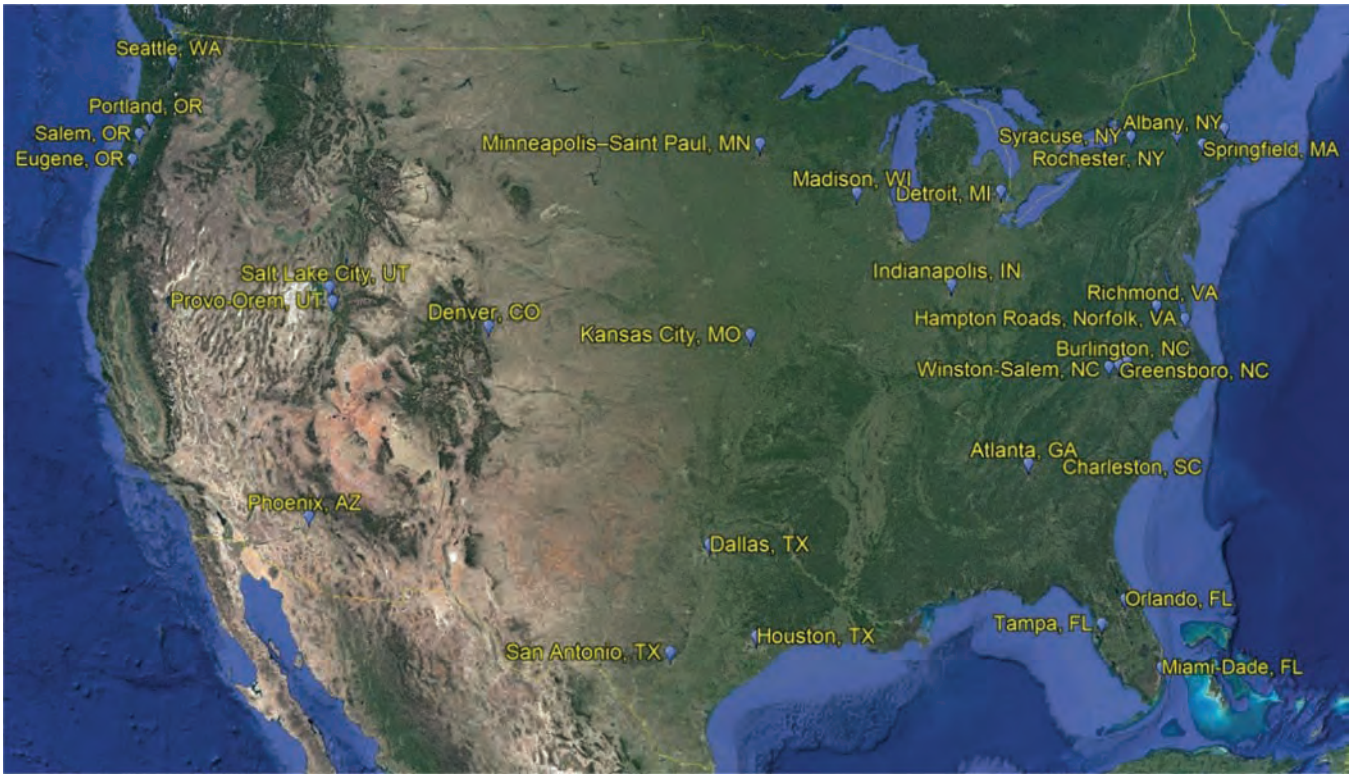

Figure B-1. Location of 31 regions in the United States (Boston not pictured).

sign and a statistically significant relationship to the outcome variables. Table B-2 presents the definition and descriptive statistics for all the endogenous (outcome) and exogenous variables investigated in the model.

Hypothesis

The hypothesis is that households that live in areas that have greater accessibility to jobs by transit will generate more transit trips, which will lead to a decrease in household VMT. This will be the direct effect of transit accessibility on VMT. By transit accessibility is meant job accessibility by transit within 30 minutes (the variable labeled *accessibility_by_transit30* in Table B-2). For transit trips, also developed were a dummy variable of zero (household with no transit trip) and one (household with at least one transit trip) to control for the excessive number of zero values—in this case, 89.2% of households with no transit use at all. In every city in the United States, infrastructure dedicated to private-vehicle travel dwarfs public transportation infrastructure. It is not surprising then that transit represents a very small proportion of total travel in the United States. Hence, use of transit is the exception rather than the rule overall in the United States, even as it is a major mode of travel in many communities.

The indirect effect will be through activity density because the hypothesis is that areas with better transit accessibility will have higher activity density and generate more non-auto trips. In addition, there is a direct path from transit accessibility to VMT to capture all the remaining reductions in VMT that result from having better accessibility by transit. Note that this path is considered as another indirect effect.

The complex causal chain described previously is best modeled with structural equation modeling (SEM). SEM is a statistical technique for evaluating complex hypotheses involving

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Table B-2. Variables used to estimate household VMT.

Variable	Description	*N*	Mean	Std. Dev.
Endogenous Variables				
lnvmt[a]	vehicle-miles traveled	81,573	31.56	31.67
transit_trips	transit trips per household	81,573	0.28	1.09
lnactivity_density	activity density within TAZ (pop + emp per square mile in 1,000s)	81,573	1.67	0.85
Exogenous Variables: Socioeconomic Characteristics				
vehicle	number of vehicles owned by household	81,573	1.93	1.04
household_size	household size	81,573	2.48	1.34
employed	number of employed persons in household	81,573	1.24	0.88
income	household income in 1,000s	81,573	77.24	49.42
Exogenous Variables: Built Environment Characteristics within TAZ				
jobpop[b]	job–population balance	81,573	0.57	0.27
entropy[c]	land use mix	81,554	0.43	0.25
intersection_density	intersection density	81560	104.2	81.3
percentage_4way	percentage of four-way intersections	81,540	25.38	20.05
accessibility_by_auto10	percentage of regional employment within 10 minutes by auto	81,573	7.83	11.87
accessibility_by_auto20	percentage of regional employment within 20 minutes by auto	81,573	30.46	26.87
accessibility_by_auto30	percentage of regional employment within 30 minutes by auto	81,573	52.52	30.46
accessibility_by_transit30	percentage of regional employment within 30 minutes by transit	81,573	20.83	24.28
Exogenous Variables: Regional Characteristics				
regional_pop	regional population in 1,000s	31	2094.14	1794.37
regional_emp	regional employment in 1,000s	31	1055.57	917.82
pop_density	regional population density	31	2186.41	747.25
fuel	average metropolitan fuel price	28	2.76	0.12
freeway	freeway lane miles per 1,000 population	28	0.72	0.28
other	other lane miles per 1,000 population	28	2.20	0.40
route_density	transit route density per square mile	28	3.02	1.97
transit_freq	transit service frequency (annual revenue miles/route miles)	28	8722.01	3233.50
tpm	annual transit passenger miles per capita	28	130.05	97.05
compactness	the compactness index	26	99.90	26.58

[a] "ln" at the beginning of a variable indicates the "natural logarithm" version of the variable.

[b] job–population balance = 1 – [ABS(employment – 0.2 * population)/(employment + 0.2 * population)]; ABS = absolute value of expression in parentheses. The value 0.2, representing a balance of employment and population, was found through trial and error to maximize the explanatory power of the variable (Ewing et al. 2015).

[c] land use entropy = – [residential share * ln(residential share) + commercial share * ln(commercial share) + public share * ln(public share)]/ln(3), where ln is the natural logarithm (Ewing et al. 2015).

multiple, interacting variables (Grace 2006). The estimation of structural equation models involves solving a set of equations. There is an equation for each "response" or "endogenous" variable in the system. They are affected by other variables and may also affect other variables. Variables that are solely predictors of other variables are termed "influences" or "exogenous" variables. They may be correlated with one another but are determined outside the system. There are several related and distinctive features of SEM that make it appropriate for this analysis (Ewing et al. 2015).

On the other hand, the data and model structure are hierarchical, with households and TAZs "nested" within regions. The best statistical approach for nested data is multilevel modeling (MLM), also called hierarchical modeling. MLM accounts for spatial dependence among observations. Ordinary least squares and other regression methods produce biased standard

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errors and inefficient regression coefficients. MLM overcomes these limitations, accounting for the dependence among observations and producing more accurate coefficient and standard error estimates (Raudenbush and Bryk 2002).

In this study, a multilevel SEM model was used to explain outcome variables and compute the transit land-use multiplier. Note that by using multilevel SEM and considering regional characteristics, separate multipliers for each individual region can be estimated, which is the whole purpose of this project. Also note that since the dataset is massive and the model is extremely complex due to the multilevel component, it will take a huge amount of time (nearly impossible) from statistical software such as *R* (i.e., *lavaan* package) or Stata (i.e., *GSEM* command) to estimate the model that is sought.

In addition, historically, SEMs have been estimated using a maximum likelihood approach to select parameter values that best reproduce the entirety of the observed variance–covariance matrix. The goodness of fit of the SEM can then be evaluated using a chi-square test comparing the estimated to the observed covariance matrix (Grace 2006). This approach, however, assumes that all observations are independent, and all variables follow a (multivariate) normal distribution (Grace 2006). It also restricts the minimum number of observations necessary to fit the SEM since there need to be sufficient degrees of freedom to estimate the whole variance–covariance matrix (the "*t rule,*" Grace 2006). These restrictions led to the parallel development of directed acyclic, or piecewise, SEMs based on applications from graph theory.

In piecewise SEM, the path diagram is translated to a set of linear (structured) equations, which are then evaluated individually. The switch from global estimation, where equations are solved simultaneously, to local estimation, where each equation is solved separately, allows for the fitting of a wide range of distributions and sampling designs (Shipley 2000, 2009). Because of that, in this study, a multilevel piecewise SEM was used, which allows estimation of a model in a very short period of time, using the *piecewiseSEM* package in *R* software for a total of 81,573 households with no missing data.

Since the household's choice to have a transit trip or not (variable called *any transit*) is a dummy outcome variable, hierarchical binary logistic regression might seem to be the best approach. However, there is a growing body of literature that explains the problem of unobserved heterogeneity in logistic regression models (Mood 2010). The literature then suggests the use of linear prediction models, especially when the sample size is huge. Because of that, and also to make the model less complex, the authors used a linear probability model for this dummy variable as well.

Result and Discussion

Figure B-2 shows the best-fit model from the multilevel piecewise SEM analysis. The diagram has been simplified to avoid confusion in understanding the paths from exogenous explanatory variables to each of the endogenous variables. In this regard, all of the socioeconomic and built environment variables that were used are called "Socioeconomic and D Variables," except job accessibility by transit, so that the direct and indirect effects of transit on VMT can be illustrated.

Unfortunately, many of the regional variables and relationships are neither theoretically nor statistically significant, possibly due to the small sample size at the regional level. Therefore, they can be dropped. One possible solution is to apply a factor analysis or principal component analysis; these are techniques for reducing the dimensionality of such a dataset, increasing interpretability but at the same time minimizing information loss. However, since the ultimate goal of this project is to provide a simple formula so that other transit agencies

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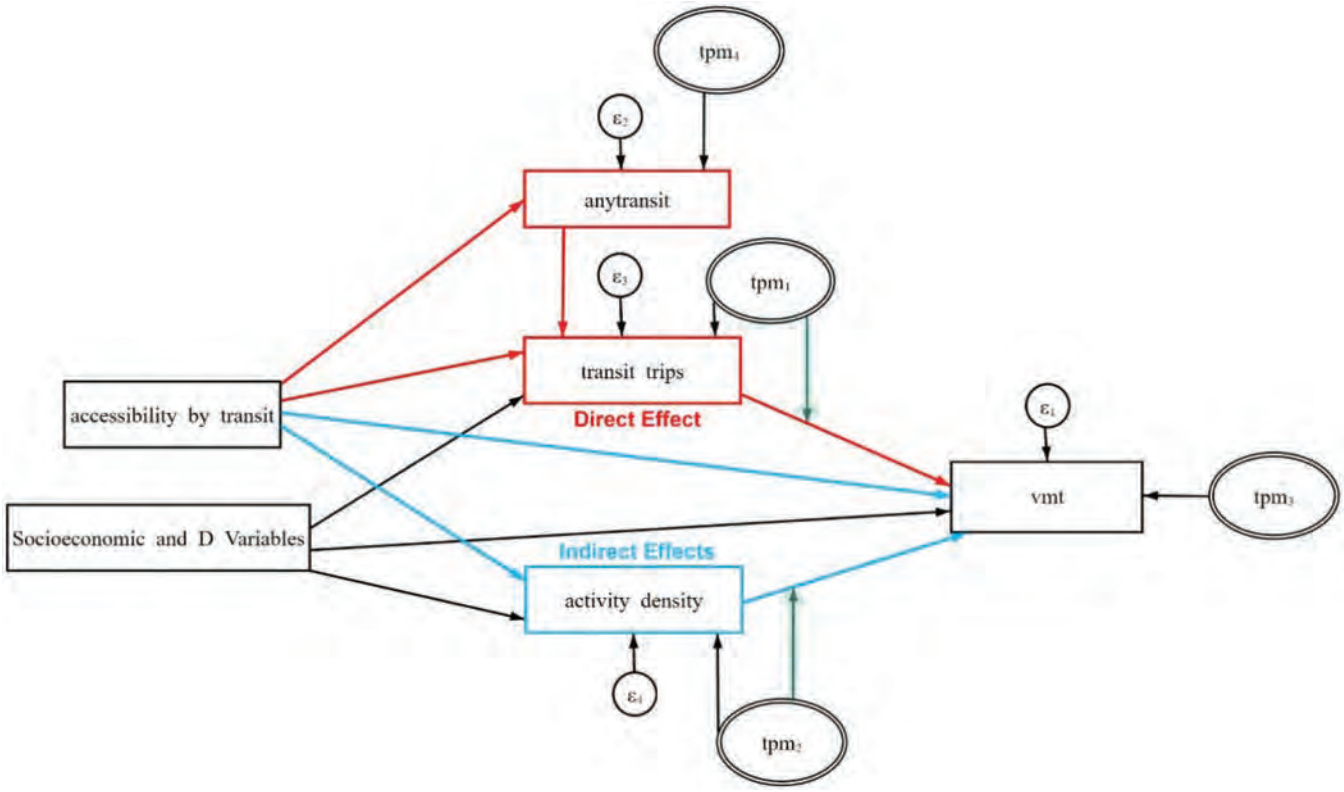

Figure B-2. Final causal path diagram (simplified).

across the United States can compute their own multipliers, it was decided not to use these data reduction techniques.

In addition, all efforts have been made to have a parsimonious model with great explanatory predictive power. The causal path diagram can undoubtedly become more complex by adding the number of vehicles owned by a household as another mediating variable. However, this will lower the interpretability of the results and make the computation of multipliers extremely difficult.

As explained in the conceptual framework, job accessibility by transit (within 30 minutes) and socioeconomic (e.g., household size) and other built environment variables (e.g., accessibility by auto within 30 minutes) have direct paths to activity density. On the other hand, these exogenous variables have direct paths to transit trips (as well as any transit) made by households. Finally, activity density, transit trips, and exogenous variables are directly affecting VMT.

The direct and indirect effects of transit accessibility on VMT, which was explained in the previous section, are shown in red and blue, respectively, in Figure B-2. Annual transit passenger miles per capita (i.e., *tpm*), which is the only regional level variable, has a direct path to each of the outcome variables. In addition, those two paths from the regional variable to the blue and red paths represent the interactions between *tpm* and activity density, any transit, and transit trips. The value of these interactions will allow separate transit land-use multipliers for each region. Note that while there are consistent datasets for 31 regions, *tpm* has been measured in 28 regions. Hence, three regions were dropped due to data availability.

Table B-3 presents the path coefficient estimates (regression coefficients) and associated statistics for direct effects of explanatory variables on outcome. Note that all variables are mean-centered to have a more meaningful interpretation of the coefficients and interactions

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Table B-3. Path coefficient estimates (regression coefficients).

Outcome	Predictor	Estimate	Std. Error	Crit. Value	*P*-Value
transit_trips	accessibility_by_transit30	0.0010	0.0001	7.1795	<0.001
transit_trips	household_size	0.0259	0.0021	12.1036	<0.001
transit_trips	employed	0.0141	0.0034	−4.1927	<0.001
transit_trips	income	−0.0008	0.0001	−14.8235	<0.001
transit_trips	entropy	0.0160	0.0106	1.5102	0.1310
transit_trips	anytransit	2.8708	0.0085	337.1042	<0.001
transit_trips	tpm	0.0001	0.0002	0.5939	0.5580
anytransit	accessibility_by_transit30	0.0017	0.0001	27.5868	<0.001
anytransit	household_size	0.0086	0.0009	9.5751	<0.001
anytransit	employed	0.0182	0.0014	12.8674	<0.001
anytransit	income	−0.0004	0.0000	−18.3775	<0.001
anytransit	entropy	0.0226	0.0044	5.0751	<0.001
anytransit	percentage_4way	0.0013	0.0001	21.316	<0.001
anytransit	tpm	0.0006	0.0001	5.7948	<0.001
activity_density	accessibility_by_transit30	0.0931	0.0035	26.2775	<0.001
activity_density	entropy	3.0119	0.2227	13.5227	<0.001
activity_density	percentage_4way	0.1743	0.0030	57.3886	<0.001
activity_density	accessibility_by_auto30	0.0759	0.0034	22.2922	<0.001
activity_density	tpm.m	0.0351	0.0073	4.8376	0.0001
vmt	household_size	4.0699	0.0884	46.0288	<0.001
vmt	employed	4.9736	0.1386	35.8733	<0.001
vmt	income	0.0565	0.0023	24.589	<0.001
vmt	accessibility_by_auto30	−0.2001	0.0069	−29.2041	<0.001
vmt	percentage_4way	−0.0803	0.0061	−13.0769	<0.001
vmt	entropy	−2.7304	0.4378	−6.2372	<0.001
vmt	accessibility_by_transit30	−0.0907	0.0071	−12.6878	<0.001
vmt	tpm	−0.0306	0.0386	−0.7932	0.4468
vmt	transit_trips	−2.8822	0.1137	−25.3414	<0.001
vmt	activity_density	−0.0978	0.0142	−6.8716	<0.001
vmt	accessibility_by_transit30: tpm	−0.0001	0.0001	−1.9948	0.0461
vmt	transit_trips: tpm	0.0020	0.0007	2.7341	0.0063
vmt	activity_density: tpm	0.0004	0.0001	4.7044	<0.001
Goodness-of-fit Measures					
Akaike Information Criterion	1431.086				
Bayesian Information Criterion	1857.176				
Fisher's C	1339.086 (p-value < 0.01)				

in the multilevel analysis. In terms of the goodness-of-fit measures, piecewise SEMs do not have an equivalent to the Tucker–Lewis index or comparative fit index. The main diagnostic is Fisher's C, which is a test to see if there are missing paths. The model has a low p-value, which suggests that one or more of the missing paths is important. However, it is suspected that this is due to the huge sample size and, hence, huge degrees of freedom, which make Fisher's C significant.

Almost all of the explanatory variables in Table B-3 are significant at the 0.05 probability level and also have the expected signs.

As expected, accessibility by transit, household size, and number of workers in a household are positively associated with any transit and transit trips. The same trend can be seen for built environment variables [i.e., land use entropy, percentage of four-way intersection (only for any transit), and annual transit passenger miles per capita vis-à-vis any transit and transit trips].

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On the other hand, household income is negatively and significantly correlated with transit trips. This is mainly due to the fact that households with higher income prefer to use their own vehicles rather than using other modes such as transit. In terms of the third endogenous variable, all of the built environment variables, including accessibility by auto and transit within 30 minutes as well as the regional variable, are highly significant and positively associated with activity density, which makes sense both intuitively and theoretically.

Household VMT is positively correlated with household size, workers, and income. These relationships suggest that households with more members, workers, and higher incomes are likely to drive more and probably own more vehicles, which is consistent with most previous studies. In terms of built environment variables, accessibility by transit and auto, activity density, land use entropy, and percentage of four-way intersections are all negatively associated with VMT. That is, households that live in dense, mixed, and well-connected areas and with greater accessibility to jobs are more likely to use other modes of travel rather than their personal vehicle.

Unsurprisingly, the any transit and transit trips variables are significantly negatively correlated with VMT. The last three rows of Table B-3 (before the goodness-of-fit measures) show the interaction between two of the outcome variables (i.e., activity density and transit trips) as well as accessibility by transit and the transit passenger miles per capita. This interaction is positive for activity density, which means that the negative coefficient of this variable alone (–0.0978) will decrease slightly (–0.0004) should the regional variable be included (i.e., transit passenger miles per capita).

In other words, an increase in the regional variable will result in a smaller effect of activity density on VMT. For transit trips, the interaction is positive too, which means that higher transit passenger miles for a region will result in a slightly smaller reduction of VMT due to the impact of transit trips. The interaction term for the transit accessibility variable, however, is negative, suggesting a larger effect of this variable on VMT reduction in regions with higher transit passenger miles per capita.

With the results presented in Table B-3, the transit land-use multiplier for each region can now be computed. If we did not have any regional variable, the direct and indirect effects could be readily computed as follows:

$$\begin{aligned}\text{Direct effect} &= (B_{\text{transit accessibility} \rightarrow \text{transit trips}} \times B_{\text{transit trips} \rightarrow \text{VMT}}) \\ &\quad + (B_{\text{transit accessibility} \rightarrow \text{anytransit}} \times B_{\text{anytransit} \rightarrow \text{transit trips}} \times B_{\text{transit trips} \rightarrow \text{VMT}}) \\ &= (0.001 \times -2.882) + (0.0017 \times 2.871 \times -2.882)\end{aligned}$$

$$\begin{aligned}\text{Indirect effect} &= (B_{\text{transit accessibility} \rightarrow \text{activity density}} \times B_{\text{activity density} \rightarrow \text{VMT}}) + B_{\text{transit accessibility} \rightarrow \text{VMT}} \\ &= (0.093 \times -0.098) + (-0.091)\end{aligned}$$

Since we have transit passenger miles per capita and its interaction with activity density, transit accessibility, and transit trips variables, the multiplier should be computed in this way:

Direct effect:

$$\begin{aligned}&[B_{\text{transit accessibility} \rightarrow \text{transit trips}} \times (B_{\text{transit trips} \rightarrow \text{VMT}} + (B_{\text{transit trips: tpm}} \times (\text{transit passenger miles} \\ &\quad \text{per capita} - 130.05)))] + [B_{\text{transit accessibility} \rightarrow \text{anytransit}} \times B_{\text{anytransit} \rightarrow \text{transit trips}} \\ &\quad \times (B_{\text{transit trips} \rightarrow \text{VMT}} + (B_{\text{transit trips: tpm}} \times (\text{transit passenger miles per capita} - 130.05)))]\end{aligned}$$

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By plugging in the coefficient values, this direct effect can be simplified to:

$$[0.001 \times (-2.882 + (0.002 \times (\text{transit passenger miles per capita} - 130.05)))]$$
$$+ [0.0017 \times 2.871 \times (-2.882 + (0.002 \times (\text{transit passenger miles per capita} - 130.05)))]$$

Indirect effect:

$$[B_{\text{transit accessibility} \rightarrow \text{activity density}} \times (B_{\text{activity density} \rightarrow \text{VMT}} + (B_{\text{activity density: tpm}} \times (\text{transit passenger miles per capita} - 130.05)))] + [B_{\text{transit accessibility} \rightarrow \text{VMT}} + (B_{\text{transit accessibility: tpm}} \times (\text{transit passenger miles per capita} - 130.05))]$$

Which can be simplified to:

$$[0.093 \times (-0.098 + (0.0004 \times (\text{transit passenger miles per capita} - 130.05)))]$$
$$+ [-0.091 + (-0.0001 \times (\text{transit passenger miles per capita} - 130.05))]$$

Where 130.05 is the average of the annual transit passenger miles (per capita) in the sample of 28 regions. So, each new region should use its annual transit passenger miles per capita and subtract that by 130.05 and use the previous equations to compute its multipliers. Table B-4 shows direct, indirect, and total effects as well as the transit land-use multiplier for each of the 28 regions.

These results suggest that transit-rich regions tend to have higher transit multipliers than transit-poor regions. The direct effect of transit accessibility on VMT is about the same in all regions. A transit trip is a transit trip, and it partially substitutes for an auto trip. It is the indirect effect that varies from region to region, which causes variance in the transit multiplier. Transit-poor regions have a smaller indirect effect of transit on VMT than do transit-rich regions, which makes sense.

The indirect effect is the main variable in the transit multiplier equation, which causes the transit multiplier to be larger in transit-rich regions. In transit-rich regions, the effect of transit is primarily through land use changes, favoring density and its effect on travel variables other than transit passenger miles. In these regions, the main effect of transit is to boost walk trips and shorten auto trips, which are both indirect effects of transit service quality.

In Seattle, for instance, with a multiplier of 9.31, each increment of additional transit accessibility produces a direct effect of 0.0137 reduction in VMT per capita, while each increment of additional transit accessibility produces an indirect effect of 0.1171. On the other hand, in a region like Detroit, with a multiplier of 6.51, each increment of additional transit accessibility produces almost a comparable direct effect of 0.0175, but a much smaller indirect effect of 0.097. This implies that there are increasing returns to scale to transit supply.

The range of the multiplier is from 6.1 to 9.5 for the regions in the sample. Note that this is not the transit land-use multiplier as usually defined, but a multiplier of total VMT reduction relative to VMT reduction directly due to transit passenger miles. The main effect of transit is not due to model shifts from auto use to transit use, but rather is due to changes in the built environments that are well served by transit. If all regions are considered simultaneously and households in all regions are treated as a single database, the average transit land-use multiplier is 7.43, which isn't far from the midpoint of the multilevel model. Transit agencies can either compute the annual transit passenger mile per capita and from that a specific multiplier, or they

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Table B-4. Transit multipliers for each of the 28 regions (sorted by the multiplier).

	Direct Effect	Indirect Effect	Total Effect	Multiplier
Boston, MA	−0.0137	−0.1171	−0.1308	9.5404
Seattle, WA	−0.0139	−0.1159	−0.1298	9.3102
Portland, OR	−0.0154	−0.1083	−0.1236	8.0470
Denver, CO	−0.0158	−0.1057	−0.1215	7.6700
Atlanta, GA	−0.0160	−0.1048	−0.1209	7.5515
Minneapolis–St. Paul, MN-WI	−0.0163	−0.1033	−0.1196	7.3413
Eugene, OR	−0.0163	−0.1031	−0.1195	7.3187
Miami, FL	−0.0165	−0.1020	−0.1186	7.1716
Salt Lake City, UT	−0.0166	−0.1019	−0.1185	7.1589
Madison, WI	−0.0170	−0.0996	−0.1166	6.8657
San Antonio, TX	−0.0171	−0.0992	−0.1162	6.8112
Houston, TX	−0.0171	−0.0989	−0.1160	6.7781
Phoenix, AZ	−0.0173	−0.0980	−0.1153	6.6663
Syracuse, NY	−0.0174	−0.0975	−0.1149	6.6077
Greensboro, NC	−0.0174	−0.0973	−0.1147	6.5883
Dallas, TX	−0.0174	−0.0971	−0.1146	6.5674
Orlando, FL	−0.0175	−0.0971	−0.1146	6.5656
Salem, OR	−0.0175	−0.0970	−0.1145	6.5521
Rochester, NY	−0.0175	−0.0970	−0.1144	6.5463
Albany, NY	−0.0175	−0.0969	−0.1144	6.5376
Detroit, MI	−0.0175	−0.0966	−0.1142	6.5062
Tampa, FL	−0.0178	−0.0953	−0.1131	6.3551
Richmond, VA	−0.0178	−0.0953	−0.1131	6.3536
Springfield, MA	−0.0178	−0.0950	−0.1129	6.3240
Kansas City, MO	−0.0180	−0.0942	−0.1122	6.2351
Winston-Salem, NC	−0.0181	−0.0936	−0.1117	6.1683
Charleston, SC	−0.0181	−0.0936	−0.1117	6.1633
Indianapolis, IN	−0.0182	−0.0932	−0.1114	6.1285

Note that these values are slightly different than the values used in the GHG calculations, which were transit-agency based. In all cases, the transit multiplier is calculated as [direct effect + indirect effect] / direct effect.

can use the average or range of the multiplier for the entire sample to estimate the total effect of transit on VMT from the direct effect.

To recapitulate, transit reduces automobile travel in two different ways: *directly* when a traveler shifts a trip from automobile to rail or bus, and *indirectly* when it creates more accessible land use and reduces automobile ownership in an area. These indirect impacts can be large, depending on the region that households reside in. The multipliers computed from these direct and indirect impacts are in an acceptable range and consistent with some of the previous research. For instance, Holtzclaw (2000) found that VMT reductions per transit passenger mile for San Francisco (a transit-rich region) and Walnut Creek were 8 in his 1991 study and 9 in his 1994 study, which are comparable to the findings of this study. Based on the formula that the authors have provided, other transit-rich regions such as New York or Los Angeles should have a multiplier with a range between 9 and 10.

Overall, the models and multipliers developed in this study have external validity missing from earlier studies, including that of *TCRP Report 176*. This is due to the fact that household data were used (as the most disaggregate level of analysis) for 28 diverse regions across the United States. For instance, the authors of *TCRP Report 176* used hundreds of UZAs as their unit of analysis (Gallivan et al. 2015). While there are some doubts about the global and single-level

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model estimated in that report (which should not let the impact of land use on VMT vary across urbanized areas, yet the authors were somehow able to do so), the main drawback of it is related to aggregation bias, which might lead to the "ecological fallacy"—the conclusion that what is true for the group (i.e., UZAs) must be true for the subgroup (i.e., households).

The authors of *TCRP Report 176* then sought to validate their results by using household travel survey data. However, they only used data for nine regions and again developed a global model without any interaction term between regional and household variables. The output, hence, will not generate different land-use effects for different regions. Instead, the authors used the average value for all of the variables (by each region) to compute the land use effects, which is a less accurate method.

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APPENDIX C

GHG Impacts by Transit Agency, 2018

This appendix presents a summary of estimated public transportation GHG impacts by transit agency for 2018 (Table C-1). These data and more are also available in the spreadsheet tool that accompanies this report.

These values were calculated based on 2018 NTD data using the methodology described in this report. As discussed in the methodology, estimations were applied to smaller transit agencies without detailed energy use and passenger mile data. Estimation methods were also used to allocate mileage and fuel use among flex-fuel vehicles, biodiesel vehicles, and other categories, as noted in the methodology.

Due to the estimation techniques required to leverage NTD data for GHG analysis, any potential reporting errors in the NTD, and the national average mode shift value used to assess passenger GHG emissions savings, **caution should be used when citing these data or making comparisons between transit agencies.** The overall purpose of this study was to update the information available on national GHG impacts of public transportation.

Providing data by transit agency is meant to aid in understanding overall GHG trends, rather than to represent an official GHG assessment of each transit agency. In cases where a transit agency has conducted its own GHG assessment, that assessment should take precedence in understanding the transit agency's GHG impact. Furthermore, public transportation provides important equity and access services that these GHG metrics alone do not capture, so these values should not be considered the full picture of a transit system's climate resilience value to a community.

Table column descriptions:

- **Transit Agency Name, State,** and **Passenger Miles** are data as reported in the NTD.
- **Transit Vehicle GHG Emissions** are the total direct, indirect, and upstream emissions of transit vehicles in metric tons of carbon dioxide equivalent (MT CO_2e) calculated as part of this project based on transit vehicle fuel use and vehicle miles and using the methods described in Chapter 2 and Appendix A.
- **Transportation and Land Use Efficiency GHG Savings** are the total direct, indirect, and upstream emissions savings from (1) transportation efficiency—the avoided personal vehicle travel of transit passengers, and (2) land use efficiency—the avoided personal vehicle travel in communities with transit. These values were calculated as part of this project based on passenger miles and using the methods described in Chapter 2, Appendix A, and Appendix B.
- **Transit Vehicle GHG Emissions per Passenger Mile** are the direct, indirect, and upstream transit vehicle GHG emissions in kg CO_2e for each transit mode calculated as part of this project divided by the passenger miles of that mode. For the purposes of this report:
  - **Bus** also includes the NTD modes "bus rapid transit," "commuter bus," "publico," and "trolleybus."

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  - **Commuter Rail** also includes NTD modes "Alaska Railroad" and "hybrid rail."
  - **Light Rail** also includes NTD modes "cable car," "inclined plane," "monorail," "automated guideway," and "streetcar rail."
  - **Van** also includes NTD modes "demand response" and "jitney."
- As a point of comparison, an average personal gasoline vehicle emitted 0.51 kg CO_2e per mile in 2018, and an average personal electric vehicle emitted 0.14 kg CO_2e per mile.
- The data in the table are sorted alphabetically by state abbreviation and then by transit agency name.

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Table C-1. GHG impacts by transit agency, 2018.

Note: The majority of transit agencies operate one or two public transportation modes. Blank cells for "Transit Vehicle GHG Emissions per Passenger Mile" indicate that data for that mode were not in the 2018 National Transit Database.

					Transit Vehicle GHG Emissions per Passenger Mile (kg CO_2e)						
Transit Agency Name	**State**	**Passenger Miles**	**Transit Vehicle GHG Emissions (MT CO_2e)**	**Transportation and Land Use Efficiency GHG Savings (MT CO_2e)**	**Bus**	**Commuter Rail**	**Ferry**	**Heavy Rail**	**Light Rail**	**Van**	**All Transit Modes**
Alaska Railroad Corporation	AK	24,178,130	9,842	26,312		0.41					0.41
Fairbanks North Star Borough	AK	2,264,911	1,677	2,354	0.81					0.44	0.74
Municipality of Anchorage	AK	23,837,684	9,222	26,478	0.47					0.26	0.39
Autauga County Commission	AL	733,577	408	736						0.56	0.56
Baldwin County Commission	AL	3,272,549	1,845	3,485						0.56	0.56
Birmingham-Jefferson County Transit Authority	AL	20,041,918	13,206	20,637	0.60					1.22	0.66
City of Gadsden	AL	838,183	1,332	850	0.23					2.32	1.59
City of Huntsville	AL	4,047,424	2,339	4,110	0.43					1.43	0.58
City of Mobile	AL	6,296,519	4,666	6,431	0.55					2.37	0.74
City of Montgomery	AL	2,893,365	2,538	2,928	0.77					2.00	0.88
East Alabama Regional Planning and Development Commission	AL	2,672,867	1,037	2,773						0.39	0.39
Lee-Russell Council of Governments	AL	1,499,142	1,362	1,506	4.39					0.64	0.91
North Central Alabama Regional Council of Governments	AL	814,078	918	824						1.13	1.13
Northwest Alabama Council of Local Governments	AL	956,485	757	969						0.79	0.79

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					Transit Vehicle GHG Emissions per Passenger Mile (kg CO_2e)						
Transit Agency Name	**State**	**Passenger Miles**	**Transit Vehicle GHG Emissions (MT CO_2e)**	**Transportation and Land Use Efficiency GHG Savings (MT CO_2e)**	**Bus**	**Commuter Rail**	**Ferry**	**Heavy Rail**	**Light Rail**	**Van**	**All Transit Modes**
Regional Planning Commission of Greater Birmingham	AL	4,171,055	436	4,185						0.10	0.10
Tuscaloosa County Parking and Transit Authority	AL	1,346,082	953	1,360	0.69					0.77	0.71
Wiregrass Transit Authority	AL	1,795,605	311	1,848						0.17	0.17
Central Arkansas Transit Authority	AR	11,516,502	9,373	11,858	0.73				1.62	1.85	0.81
City of Fort Smith	AR	1,382,683	893	1,400	0.04					2.47	0.65
City of Hot Springs	AR	779,156	489	791	0.58					0.83	0.63
City of Jonesboro	AR	686,563	553	694						0.81	0.81
City of Pine Bluff	AR	447,392	526	451	0.70					2.11	1.17
Ozark Regional Transit	AR	1,645,346	1,192	1,655	0.65					1.55	0.72
University of Arkansas, Fayetteville	AR	6,796,479	1,661	6,970	0.24					0.50	0.24
City of Glendale	AZ	517,775	940	518	1.31					2.13	1.82
City of Peoria	AZ	97,606	202	98						2.07	2.07
City of Phoenix Public Transit Department	AZ	135,945,111	90,754	141,350	0.63					2.16	0.67
City of Scottsdale	AZ	765,303	828	765	1.08						1.08
City of Sierra Vista	AZ	686,493	315	696	0.13					1.98	0.46
City of Tucson	AZ	79,851,668	21,862	88,678	0.19				0.61	1.70	0.27
Northern Arizona Intergovernmental Public Transportation Authority	AZ	8,117,447	2,755	9,200	0.33					0.49	0.34
Pima Association of Governments	AZ	2,532,310	245	2,540						0.10	0.10
Regional Public Transportation Authority	AZ	106,853,640	47,523	110,172	0.65					0.12	0.44
Town of Oro Valley	AZ	863,892	807	865						0.93	0.93
Valley Metro Rail, Inc.	AZ	113,208,491	11,051	117,146					0.10		0.10

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					Transit Vehicle GHG Emissions per Passenger Mile (kg CO_2e)						
Transit Agency Name	**State**	**Passenger Miles**	**Transit Vehicle GHG Emissions (MT CO_2e)**	**Transportation and Land Use Efficiency GHG Savings (MT CO_2e)**	**Bus**	**Commuter Rail**	**Ferry**	**Heavy Rail**	**Light Rail**	**Van**	**All Transit Modes**
Yuma County Intergovernmental Public Transportation Authority	AZ	6,788,699	1,639	7,000	0.28					0.16	0.24
Access Services	CA	25,915,355	23,311	25,971						0.90	0.90
Alameda-Contra Costa Transit District	CA	207,299,071	80,991	217,069	0.34					1.69	0.39
Altamont Corridor Express	CA	61,400,684	5,764	62,092		0.09					0.09
Anaheim Transportation Network	CA	19,086,458	6,695	19,116	0.34						0.35
Antelope Valley Transit Authority	CA	29,394,056	9,319	29,463	0.31					0.58	0.32
Butte County Association of Governments	CA	5,955,234	4,764	6,367	0.70					1.64	0.80
California Vanpool Authority	CA	126,495,990	10,217	129,659						0.08	0.08
Central Contra Costa Transit Authority	CA	17,138,216	10,465	17,668	0.51					1.73	0.61
City and County of San Francisco	CA	445,233,922	84,969	517,802	0.22				0.11	1.60	0.19
City of Agoura Hills	CA	157,398	169	157						1.07	1.07
City of Alhambra	CA	2,460,419	813	2,461	0.34					0.30	0.33
City of Arcadia	CA	675,284	384	675						0.57	0.57
City of Atascadero	CA	223,962	66	225						0.29	0.29
City of Avalon	CA	248,996	37	249						0.15	0.15
City of Azusa	CA	616,759	132	617						0.21	0.21
City of Baldwin Park	CA	691,833	626	692	1.28					0.18	0.90
City of Bell	CA	226,034	72	226						0.32	0.32
City of Bell Gardens	CA	1,214,311	194	1,214						0.16	0.16
City of Bellflower	CA	446,721	265	447						0.59	0.59
City of Beverly Hills	CA	192,286	55	192						0.29	0.29
City of Burbank	CA	897,729	1,238	898	1.38						1.38

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					Transit Vehicle GHG Emissions per Passenger Mile (kg CO_2e)						
Transit Agency Name	State	Passenger Miles	Transit Vehicle GHG Emissions (MT CO_2e)	Transportation and Land Use Efficiency GHG Savings (MT CO_2e)	Bus	Commuter Rail	Ferry	Heavy Rail	Light Rail	Van	All Transit Modes
City of Calabasas	CA	442,923	311	443	0.23					5.04	0.70
City of Camarillo	CA	1,964,029	829	2,024						0.42	0.42
City of Carson	CA	971,547	1,181	971	1.22						1.22
City of Cerritos	CA	827,771	302	828	0.36						0.36
City of Commerce	CA	2,185,328	1,440	2,185	0.62					1.74	0.66
City of Compton	CA	431,994	353	432	0.24					2.64	0.82
City of Corona	CA	1,540,820	1,053	1,542	1.10					0.47	0.68
City of Covina	CA	336,274	116	336						0.34	0.34
City of Cudahy	CA	474,585	42	475	0.09						0.09
City of Culver City	CA	16,121,308	11,283	16,142	0.70					4.60	0.70
City of Davis	CA	317,748	91	319						0.29	0.29
City of Delano	CA	564,379	594	565						1.05	1.05
City of Downey	CA	904,033	353	904	0.41					0.36	0.39
City of Duarte	CA	665,072	270	665	0.41						0.41
City of El Monte	CA	2,577,487	983	2,578	0.38					0.40	0.38
City of Elk Grove	CA	6,580,950	3,292	6,607	0.44					3.26	0.50
City of Fairfield	CA	9,025,362	5,439	9,038	0.57					1.85	0.60
City of Folsom	CA	542,123	450	542	1.06					0.53	0.83
City of Fresno	CA	27,423,127	18,232	28,715	0.59					1.91	0.66
City of Gardena	CA	11,356,330	5,812	11,366	0.50					1.66	0.51
City of Glendale	CA	3,554,368	3,353	3,555	0.93					1.08	0.94
City of Glendora	CA	602,095	501	602						0.83	0.83
City of Inglewood	CA	565,785	356	566	0.65					0.63	0.63
City of La Mirada	CA	120,636	232	121						1.92	1.92
City of Laguna Beach	CA	1,871,078	799	1,877	0.43						0.43
City of Lakewood	CA	272,644	114	273						0.42	0.42
City of Lawndale	CA	255,216	312	255						1.22	1.22
City of Lodi	CA	1,639,920	1,268	1,683	0.49					1.34	0.77
City of Lompoc	CA	817,987	433	820						0.53	0.53
City of Los Angeles	CA	54,897,817	43,831	55,161	0.72					5.21	0.80

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					Transit Vehicle GHG Emissions per Passenger Mile (kg CO_2e)						
Transit Agency Name	State	Passenger Miles	Transit Vehicle GHG Emissions (MT CO_2e)	Transportation and Land Use Efficiency GHG Savings (MT CO_2e)	Bus	Commuter Rail	Ferry	Heavy Rail	Light Rail	Van	All Transit Modes
City of Lynwood	CA	796,182	478	796	0.20						0.60
City of Madera	CA	1,014,609	1,174	1,029						1.16	1.16
City of Manhattan Beach	CA	453,354	105	453						0.23	0.23
City of Manteca	CA	410,325	251	412						0.61	0.61
City of Maywood	CA	501,420	151	501						0.30	0.30
City of Modesto	CA	9,797,700	6,187	10,000	0.60					1.14	0.63
City of Monrovia	CA	547,629	115	548						0.21	0.21
City of Montebello	CA	20,522,183	9,719	20,557	0.47						0.47
City of Monterey Park	CA	1,213,158	761	1,213	0.48					1.62	0.63
City of Moorpark	CA	205,435	364	206	1.77						1.77
City of Norwalk	CA	6,208,325	3,857	6,211	0.60					2.13	0.62
City of Pasadena	CA	3,051,896	879	3,052	0.18					1.30	0.29
City of Petaluma	CA	946,834	760	962	0.68					2.74	0.80
City of Pico Rivera	CA	142,591	42	143						0.30	0.30
City of Porterville	CA	2,801,931	2,539	2,927	0.92					0.74	0.91
City of Redondo Beach	CA	1,506,913	1,537	1,507	0.92					3.41	1.02
City of Riverside	CA	1,171,169	1,141	1,172						0.97	0.97
City of Rosemead	CA	438,574	261	439						0.60	0.60
City of Roseville	CA	1,806,409	2,281	1,808	1.49					0.68	1.26
City of San Luis Obispo	CA	2,939,693	1,304	3,105	0.44						0.44
City of Santa Clarita	CA	21,115,775	13,601	21,151	0.60					1.73	0.64
City of Santa Fe Springs	CA	113,203	29	113						0.26	0.26
City of Santa Maria	CA	2,825,788	2,978	2,874	1.03					1.34	1.05
City of Santa Monica	CA	49,242,239	22,723	49,453	0.46					2.65	0.46
City of Santa Rosa	CA	7,229,615	3,131	7,417	0.40					1.46	0.43
City of Simi Valley	CA	1,817,469	2,057	1,817	1.21					1.02	1.13
City of South Gate	CA	938,359	693	938						0.74	0.74
City of South Pasadena	CA	169,429	122	169						0.72	0.72
City of Thousand Oaks	CA	2,224,953	2,516	2,225	1.51					0.98	1.13
City of Torrance	CA	18,221,365	7,462	18,248	0.41						0.41

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					Transit Vehicle GHG Emissions per Passenger Mile (kg CO_2e)						
Transit Agency Name	**State**	**Passenger Miles**	**Transit Vehicle GHG Emissions (MT CO_2e)**	**Transportation and Land Use Efficiency GHG Savings (MT CO_2e)**	**Bus**	**Commuter Rail**	**Ferry**	**Heavy Rail**	**Light Rail**	**Van**	**All Transit Modes**
City of Tracy	CA	936,660	965	948	1.08					0.93	1.03
City of Tulare	CA	1,348,326	1,386	1,357	0.92					2.78	1.03
City of Turlock	CA	566,211	381	570	0.70					0.54	0.67
City of Union City	CA	1,439,786	1,929	1,440	1.48					0.84	1.34
City of Vacaville	CA	1,912,747	1,705	1,956	0.95					0.55	0.89
City of Visalia	CA	10,077,280	6,712	10,599	0.63					1.81	0.67
City of West Covina	CA	472,561	440	472						0.93	0.93
City of West Hollywood	CA	645,844	252	646						0.39	0.39
City of Whittier	CA	1,159,795	279	1,160						0.24	0.24
County of Placer	CA	7,864,145	5,336	7,898	0.69					0.60	0.68
County of Sonoma	CA	8,353,546	5,556	8,561	0.59					1.43	0.67
County of Ventura	CA	322,500	335	323						1.04	1.04
Easy Lift Transportation	CA	1,249,879	1,084	1,258						0.87	0.87
El Dorado County Transit Authority	CA	6,801,000	2,920	6,829	0.33					1.53	0.43
Foothill Transit	CA	95,300,385	57,314	95,995	0.60						0.60
Gold Coast Transit	CA	15,252,747	10,198	15,965	0.60					1.73	0.67
Golden Empire Transit District	CA	22,346,155	19,338	23,418	0.82					3.20	0.87
Golden Gate Bridge, Highway and Transportation District	CA	86,431,958	45,029	88,697	0.28		1.01			1.76	0.52
Imperial County Transportation Commission	CA	8,830,401	3,130	9,668	0.30					0.69	0.35
Kings County Area Public Transit Agency	CA	4,550,413	2,598	4,573	0.55					2.33	0.57
Livermore/Amador Valley Transit Authority	CA	7,935,191	4,910	8,034	0.61					0.85	0.62
Long Beach Transit	CA	74,007,157	26,984	74,491	0.36					1.71	0.36

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					Transit Vehicle GHG Emissions per Passenger Mile (kg CO_2e)						
Transit Agency Name	**State**	**Passenger Miles**	**Transit Vehicle GHG Emissions (MT CO_2e)**	**Transportation and Land Use Efficiency GHG Savings (MT CO_2e)**	**Bus**	**Commuter Rail**	**Ferry**	**Heavy Rail**	**Light Rail**	**Van**	**All Transit Modes**
Los Angeles County Department of Public Works – East L.A.	CA	3,914,803	1,104	3,915	0.27					0.42	0.28
Los Angeles County Department of Public Works – South Whittier	CA	1,046,265	783	1,046	0.75						0.75
Los Angeles County Department of Public Works – Whittier	CA	543,525	428	543						0.79	0.79
Los Angeles County Dept. of Public Works – Florence-Firestone	CA	922,451	399	922	0.25						0.43
Los Angeles County Dept. of Public Works – Willowbrook, etc.	CA	105,695	71	106						0.67	0.67
Los Angeles County Metropolitan Transportation Authority	CA	2,014,910,655	471,284	2,255,769	0.34			0.10	0.08	0.13	0.23
Marin County Transit District	CA	13,053,770	7,546	13,109	0.52					1.54	0.58
Monterey-Salinas Transit	CA	30,018,344	15,118	33,549	0.45					1.33	0.50
Napa Valley Transportation Authority	CA	10,288,338	5,452	11,790	0.49					1.02	0.53
North County Transit District	CA	89,747,700	37,127	92,783	0.66	0.27				1.26	0.41
Omnitrans	CA	62,431,233	39,260	62,725	0.60					0.96	0.63
Orange County Transportation Authority	CA	214,198,266	104,213	217,628	0.51					0.43	0.49
Palos Verdes Peninsula Transit Authority	CA	638,183	1,319	638	0.25						2.07
Paratransit, Inc.	CA	3,537,337	6,364	3,545						1.80	1.80

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					Transit Vehicle GHG Emissions per Passenger Mile (kg CO_2e)						
Transit Agency Name	State	Passenger Miles	Transit Vehicle GHG Emissions (MT CO_2e)	Transportation and Land Use Efficiency GHG Savings (MT CO_2e)	Bus	Commuter Rail	Ferry	Heavy Rail	Light Rail	Van	All Transit Modes
Peninsula Corridor Joint Powers Board	CA	411,267,970	54,000	450,050	0.72	0.13					0.13
Redding Area Bus Authority	CA	5,248,609	2,603	5,512	0.42					1.30	0.50
Riverside County Transportation Commission	CA	490,826	70	491						0.14	0.14
Riverside Transit Agency	CA	70,297,387	39,711	70,593	0.49					1.81	0.56
Sacramento Regional Transit District	CA	103,512,084	33,698	110,594	0.67				0.12	6.88	0.33
San Diego Association of Governments	CA	85,605,989	8,461	86,062						0.10	0.10
San Diego Metropolitan Transit System	CA	413,586,178	103,298	483,282	0.43				0.05	1.40	0.25
San Francisco Bay Area Rapid Transit District	CA	1,789,223,155	81,815	2,947,385		0.09		0.04	0.58		0.05
San Francisco Bay Area Water Emergency Transportation Authority	CA	42,864,299	36,237	43,447			0.85				0.85
San Joaquin Council	CA	3,839,997	440	3,866						0.11	0.11
San Joaquin Regional Transit District	CA	18,556,500	7,184	19,185	0.39						0.39
San Luis Obispo Council of Governments	CA	355,831	271	356						0.76	0.76
San Luis Obispo Regional Transit Authority	CA	12,413,003	4,345	12,977	0.30					1.41	0.35
San Mateo County Transit District	CA	49,520,038	30,938	50,340	0.60					1.02	0.62
Santa Barbara Metropolitan Transit District	CA	25,748,791	7,620	29,803	0.30						0.30
Santa Clara Valley Transportation Authority	CA	189,969,055	61,809	197,988	0.37				0.12	0.92	0.33

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					Transit Vehicle GHG Emissions per Passenger Mile (kg CO_2e)						
Transit Agency Name	**State**	**Passenger Miles**	**Transit Vehicle GHG Emissions (MT CO_2e)**	**Transportation and Land Use Efficiency GHG Savings (MT CO_2e)**	**Bus**	**Commuter Rail**	**Ferry**	**Heavy Rail**	**Light Rail**	**Van**	**All Transit Modes**
Santa Cruz Metropolitan Transit District	CA	30,361,339	9,675	35,003	0.30					1.62	0.32
Solano County Transit	CA	11,248,452	5,649	11,280	0.46					3.65	0.50
Sonoma-Marin Area Rail Transit District	CA	16,174,174	3,395	16,250		0.21					0.21
Southern California Regional Rail Authority	CA	438,553,704	102,520	449,760		0.23					0.23
Stanislaus County dba Stanislaus Regional Transit	CA	2,002,067	4,452	2,011	1.85					2.85	2.22
SunLine Transit Agency	CA	41,488,577	14,877	42,321	0.32					0.82	0.36
The Eastern Contra Costa Transit Authority	CA	16,587,903	8,541	16,927	0.45					1.88	0.51
Transit Joint Powers Authority for Merced County	CA	5,504,939	5,015	5,647	0.77					3.26	0.91
University of California, Davis	CA	8,674,173	2,924	9,901	0.34						0.34
Ventura County Transportation Commission	CA	13,955,967	5,945	13,970	0.40					3.29	0.43
Victor Valley Transit Authority	CA	44,020,329	16,753	44,966	0.86					0.20	0.38
Western Contra Costa Transit Authority	CA	14,754,297	5,676	14,825	0.37					1.17	0.38
Yolo County Transportation District	CA	13,767,948	6,774	13,878	0.47					1.41	0.49
Yuba-Sutter Transit Authority	CA	8,093,041	3,527	8,131	0.38					1.38	0.44
City of Colorado Springs	CO	14,879,292	9,697	14,956	0.61					0.76	0.65
City of Fort Collins	CO	13,027,551	5,058	13,429	0.39					0.65	0.39
City of Loveland	CO	468,307	512	469	1.07					2.17	1.09
City of Pueblo	CO	3,159,566	1,699	3,241	0.50					0.98	0.54

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					Transit Vehicle GHG Emissions per Passenger Mile (kg CO_2e)						
Transit Agency Name	**State**	**Passenger Miles**	**Transit Vehicle GHG Emissions (MT CO_2e)**	**Transportation and Land Use Efficiency GHG Savings (MT CO_2e)**	**Bus**	**Commuter Rail**	**Ferry**	**Heavy Rail**	**Light Rail**	**Van**	**All Transit Modes**
County of Mesa	CO	3,551,881	3,131	3,661	0.18					4.92	0.88
Denver Regional Transportation District	CO	612,310,467	192,274	793,708	0.37	0.16			0.22	1.72	0.31
Enterprise – Denver	CO	7,732,123	949	7,749						0.12	0.12
Greeley, City Of	CO	3,721,672	2,307	3,853	0.56					1.08	0.62
North Front Range Transportation and Air Quality Planning Council	CO	3,326,548	654	3,330						0.20	0.20
Seniors' Resource Center, Inc	CO	1,930,979	1,108	1,932						0.57	0.57
Connecticut Department of Transportation	CT	21,896,651	17,353	22,250	0.38	0.88					0.79
Connecticut Department of Transportation – CTTRANSIT – Hartford Division	CT	103,268,712	31,239	111,164	0.30						0.30
Connecticut Department of Transportation – CTTRANSIT New Britain – Dattco	CT	6,132,299	3,475	6,176	0.57						0.57
Connecticut Department of Transportation – CTTRANSIT New Haven Division	CT	25,517,192	13,700	25,942	0.54						0.54
Connecticut Department of Transportation – CTTRANSIT Stamford Division	CT	9,819,844	4,567	9,824	0.47						0.47
Connecticut Department of Transportation – CTTRANSIT New Britain	CT	4,045,171	2,771	4,064	0.69						0.69
Connecticut Department of Transportation – CTTransit Waterbury – NET	CT	5,030,586	4,942	5,067	0.83					1.90	0.98
Estuary Transit District	CT	492,167	689	492						1.40	1.40

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Transit Agency Name	**State**	**Passenger Miles**	**Transit Vehicle GHG Emissions (MT CO_2e)**	**Transportation and Land Use Efficiency GHG Savings (MT CO_2e)**	**Bus**	**Commuter Rail**	**Ferry**	**Heavy Rail**	**Light Rail**	**Van**	**All Transit Modes**
Greater Bridgeport Transit Authority	CT	16,889,892	6,738	17,230	0.37					1.16	0.40
Greater Hartford Transit District	CT	4,439,221	7,348	4,462						1.66	1.66
Housatonic Area Regional Transit	CT	5,036,095	3,389	5,061	0.59					1.66	0.67
Middletown Transit District	CT	1,460,606	1,266	1,463	0.95					0.55	0.87
Milford Transit District	CT	1,643,797	754	1,647	0.19					1.89	0.46
Norwalk Transit District	CT	5,762,425	4,444	5,795	0.62					2.15	0.77
Southeast Area Transit District	CT	5,653,091	3,285	5,823	0.56					5.15	0.58
The Greater New Haven Transit District	CT	1,630,070	3,120	1,632						1.91	1.91
Valley Transit District	CT	396,713	443	397						1.12	1.12
DDOT – Progressive Transportation Services Administration	DC	7,063,559	7,117	7,074	0.86				1.91		1.01
National Capital Region Transportation Planning Board	DC	404,252	190	404						0.47	0.47
Washington Metropolitan Area Transit Authority	DC	1,704,431,708	370,253	2,252,945	0.40			0.15		1.43	0.22
Delaware Transit Corporation	DE	46,481,525	42,185	46,895	0.78					1.30	0.91
Board of County Commissioners, Palm Beach County	FL	64,307,736	39,963	65,128	0.44					1.37	0.62
Brevard Board of County Commissioners	FL	19,189,782	7,925	20,004	0.30					0.61	0.41
Broward County Board of County Commissioners	FL	146,623,042	77,802	150,963	0.46					1.51	0.53

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					Transit Vehicle GHG Emissions per Passenger Mile (kg CO_2e)						
Transit Agency Name	State	Passenger Miles	Transit Vehicle GHG Emissions (MT CO_2e)	Transportation and Land Use Efficiency GHG Savings (MT CO_2e)	Bus	Commuter Rail	Ferry	Heavy Rail	Light Rail	Van	All Transit Modes
Central Florida Commuter Rail	FL	12,044,554	6,727	12,148		0.56					0.56
Central Florida Regional Transportation Authority	FL	153,806,088	42,700	168,830	0.19					0.85	0.28
Charlotte County Government	FL	1,384,575	1,316	1,387						0.95	0.95
City of Coconut Creek	FL	406,794	553	407						1.36	1.36
City of Coral Springs	FL	229,679	71	230						0.31	0.31
City of Dania Beach	FL	159,486	174	159						1.09	1.09
City of Deerfield Beach	FL	285,522	292	285						1.02	1.02
City of Fort Lauderdale	FL	1,174,242	1,113	1,174	0.74		18.69				0.95
City of Gainesville	FL	28,812,266	14,265	34,190	0.48					0.60	0.50
City of Hallandale Beach	FL	1,128,400	488	1,128						0.43	0.43
City of Hollywood	FL	349,746	234	350						0.67	0.67
City of Lauderdale Lakes	FL	370,644	141	371						0.38	0.38
City of Lauderhill	FL	1,990,740	599	1,991						0.30	0.30
City of Lighthouse Point	FL	44,430	77	44						1.73	1.73
City of Margate	FL	665,264	375	665						0.56	0.56
City of Miramar	FL	490,648	615	491						1.25	1.25
City of Ocala	FL	2,254,963	1,685	2,290	0.73					1.20	0.75
City of Pembroke Pines	FL	766,003	573	766						0.75	0.75
City of Pompano Beach	FL	331,384	401	331						1.21	1.21
City of Tallahassee	FL	10,161,914	8,776	10,645	0.80					1.71	0.86
City of Tamarac	FL	212,208	161	212						0.76	0.76
City of West Park	FL	28,303	30	28						1.05	1.05
Collier County	FL	7,441,092	5,049	7,639	0.58					1.11	0.68
Council on Aging of St. Lucie, Inc.	FL	3,441,130	2,296	3,475	0.49					1.13	0.67
County of Citrus	FL	590,780	660	595						1.12	1.12
County of Miami-Dade	FL	512,070,547	163,319	567,630	0.34			0.22	0.62	0.40	0.32
County of Volusia	FL	16,821,764	13,043	17,416	0.64					1.32	0.78

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					Transit Vehicle GHG Emissions per Passenger Mile (kg CO_2e)						
Transit Agency Name	**State**	**Passenger Miles**	**Transit Vehicle GHG Emissions (MT CO_2e)**	**Transportation and Land Use Efficiency GHG Savings (MT CO_2e)**	**Bus**	**Commuter Rail**	**Ferry**	**Heavy Rail**	**Light Rail**	**Van**	**All Transit Modes**
Escambia County Board of County Commissioners	FL	7,945,620	5,516	8,151	0.59					1.61	0.69
Flagler County Public Transportation	FL	1,346,810	1,102	1,352						0.82	0.82
Hernando County Board of County Commissioners	FL	763,035	1,460	767	2.12					1.48	1.91
Hillsborough Area Regional Transit Authority	FL	72,011,177	30,744	74,376	0.40				0.38	1.80	0.43
Indian River County	FL	5,972,876	2,838	6,241	0.39					1.83	0.48
Jacksonville Transportation Authority	FL	69,584,245	39,474	74,782	0.46		7.90		0.41	1.90	0.57
Lake County Board of County Commissioners	FL	3,431,033	3,616	3,438	0.73					1.58	1.05
Lakeland Area Mass Transit District	FL	7,206,833	5,694	7,330	0.58					2.70	0.79
Lee County	FL	20,720,059	10,082	21,286	0.46					0.59	0.49
Manatee County Board of County Commissioners	FL	6,829,794	5,093	6,909	0.66					1.31	0.75
Martin County	FL	707,414	1,079	709	1.48					1.98	1.53
Okaloosa County Board of County Commissioners	FL	867,667	2,365	872						1.62	2.73
Pasco County Board of County Commissioners	FL	5,272,495	5,323	5,284	0.90					2.49	1.01
Pinellas Suncoast Transit Authority	FL	58,625,785	33,285	60,186	0.54					1.39	0.57
Sarasota County	FL	13,635,007	10,501	13,887	0.69					1.29	0.77
South Florida Regional Transportation Authority	FL	124,077,030	45,961	127,173	0.74	0.36					0.37
St Johns County	FL	2,186,313	1,549	2,263						0.71	0.71
Tampa Bay Area Regional Transit Authority	FL	7,290,642	1,102	7,305						0.15	0.15

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The Looper Group, Inc.	FL	55,429	115	55	2.08						2.08
Town of Davie	FL	756,127	644	756						0.85	0.85
Town of Hillsboro Beach	FL	45,523	57	46						1.24	1.24
Town of Lauderdale-By-The-Sea	FL	150,781	115	151						0.76	0.76
Athens-Clarke County Unified Government	GA	5,630,382	3,440	5,908	0.59					4.32	0.61
Augusta Richmond County Transit Department	GA	2,524,477	2,137	2,542	0.76					2.14	0.85
Center for Pan Asian Community Services, Inc.	GA	330,573	159	331						0.48	0.48
Chatham Area Transit Authority	GA	8,906,227	3,865	9,246	0.25		1.55			1.52	0.43
Cherokee County Board of Commissioners	GA	1,054,800	555	1,055						0.53	0.53
City of Albany	GA	4,126,577	1,764	4,327	0.37					3.48	0.43
City of Atlanta	GA	364,699	339	365					0.93		0.93
City of Hinesville	GA	74,199	330	74	4.43						4.45
City of Rome	GA	5,010,744	1,593	5,488	0.28					1.89	0.32
Cobb County	GA	18,415,986	11,859	18,495	0.60					2.48	0.64
Columbus Consolidated Government	GA	6,089,228	4,205	6,251	0.69					0.70	0.69
County of Douglas	GA	2,871,717	681	2,873						0.24	0.24
Enterprise Rideshare	GA	28,992,306	2,397	29,164						0.08	0.08
Georgia State Road and Tollway Authority	GA	45,122,110	15,320	45,612	0.34						0.34
Gwinnett County Board of Commissioners	GA	19,559,049	8,165	19,649	0.39					2.28	0.42
Hall Area Transit	GA	740,000	1,096	744						1.48	1.48
Henry County	GA	1,252,918	681	1,253						0.54	0.54

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Transit Agency Name	**State**	**Passenger Miles**	**Transit Vehicle GHG Emissions (MT CO_2e)**	**Transportation and Land Use Efficiency GHG Savings (MT CO_2e)**	**Bus**	**Commuter Rail**	**Ferry**	**Heavy Rail**	**Light Rail**	**Van**	**All Transit Modes**
Macon-Bibb County Transit Authority	GA	3,507,986	3,586	3,607	0.47					3.82	1.02
Metropolitan Atlanta Rapid Transit Authority	GA	705,533,205	147,889	839,895	0.36			0.10		1.52	0.21
University of Georgia	GA	6,215,385	4,328	6,554	0.68					9.02	0.70
City and County of Honolulu	HI	324,927,388	80,576	488,394	0.21					1.05	0.25
County of Maui	HI	20,618,030	6,495	31,524	0.24					0.97	0.31
Ames Transit Agency	IA	10,627,324	5,008	12,937	0.47					1.74	0.47
City of Bettendorf	IA	448,443	349	449						0.78	0.78
City of Cedar Rapids	IA	6,301,868	3,601	6,552	0.53					1.10	0.57
City of Coralville	IA	1,527,046	675	1,551	0.44						0.44
City of Davenport	IA	2,523,423	1,991	2,548	0.79						0.79
City of Dubuque	IA	2,919,389	2,081	3,061	0.79					0.58	0.71
City of Iowa City	IA	3,231,165	2,446	3,340	0.76						0.76
City of Sioux City	IA	3,898,263	2,189	4,058	0.49					2.48	0.56
County of Johnson	IA	556,790	922	560	14.51					1.65	1.66
Des Moines Area Regional Transit Authority	IA	27,374,988	12,222	29,273	0.54					0.27	0.45
Metropolitan Transit Authority of Black Hawk County	IA	2,604,332	2,804	2,671	1.15					0.98	1.08
River Bend Transit	IA	1,554,926	1,742	1,564	1.81					1.11	1.12
University of Iowa	IA	5,207,245	2,683	5,495	0.49					4.22	0.52
Ada County Highway District	ID	11,513,845	1,142	11,807						0.10	0.10
Boise State University	ID	882,489	284	885						0.32	0.32
City of Lewiston	ID	324,291	250	326						0.77	0.77
City of Pocatello	ID	2,212,755	1,425	2,291	0.53					0.72	0.64
Coeur d'Alene Tribe	ID	1,127,641	1,843	1,142	1.70					1.14	1.63
Kootenai County	ID	644,767	268	649						0.42	0.42

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Transit Agency Name	**State**	**Passenger Miles**	**Transit Vehicle GHG Emissions (MT CO_2e)**	**Transportation and Land Use Efficiency GHG Savings (MT CO_2e)**	**Bus**	**Commuter Rail**	**Ferry**	**Heavy Rail**	**Light Rail**	**Van**	**All Transit Modes**
Targhee Regional Public Transit Authority	ID	966,344	1,052	978						1.09	1.09
Treasure Valley Transit	ID	1,064,464	1,675	1,073						1.57	1.57
Valley Regional Transit	ID	6,765,813	5,370	6,866	0.71					1.99	0.79
Bloomington-Normal Public Transit System	IL	7,222,777	1,613	7,669	0.17					0.92	0.22
Boone County Council on Aging	IL	510,628	236	512						0.46	0.46
Champaign-Urbana Mass Transit District	IL	21,552,913	3,261	25,426	0.13					1.03	0.15
Chicago Transit Authority	IL	1,992,826,737	461,817	2,586,914	0.35			0.18			0.23
Chicago Water Taxi (Wendella)	IL	743,343	398	743			0.54				0.54
City of Danville	IL	2,588,347	1,737	2,626	0.50					3.09	0.67
City of Decatur	IL	3,381,444	1,015	3,518	0.24					2.66	0.30
Greater Peoria Mass Transit District	IL	17,310,246	3,565	18,594	0.11					1.82	0.21
Jackson County Mass Transit District	IL	702,902	685	711	0.97						0.98
Madison County Transit District	IL	19,319,298	4,770	19,500	0.27					0.18	0.25
Northeast Illinois Regional Commuter Railroad Corporation	IL	1,518,703,416	360,366	1,832,974		0.24					0.24
Pace – Suburban Bus Division	IL	211,420,371	93,101	216,985	0.46					0.34	0.44
Pace-Suburban Bus Division, ADA Paratransit Services	IL	36,963,176	40,250	37,126						1.09	1.09
Rides Mass Transit District	IL	10,622,485	6,657	12,651	0.23						0.63

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Transit Agency Name	**State**	**Passenger Miles**	**Transit Vehicle GHG Emissions (MT CO_2e)**	**Transportation and Land Use Efficiency GHG Savings (MT CO_2e)**	**Bus**	**Commuter Rail**	**Ferry**	**Heavy Rail**	**Light Rail**	**Van**	**All Transit Modes**
River Valley Metro Mass Transit District	IL	6,060,439	3,781	6,576	0.58					2.56	0.62
Rock Island County Metropolitan Mass Transit District	IL	10,254,944	7,612	10,675	0.75		0.48			0.73	0.74
Rockford Mass Transit District	IL	7,753,766	5,493	7,938	0.59					1.50	0.71
Springfield Mass Transit District	IL	6,171,048	5,387	6,436	0.80					1.66	0.87
Voluntary Action Center	IL	1,737,350	1,393	1,786	0.53					0.94	0.80
Access Johnson County	IN	1,356,474	1,086	1,358						0.80	0.80
Bloomington Public Transportation Corporation	IN	6,670,254	3,813	7,137	0.54					2.06	0.57
Central Indiana Regional Transportation Authority	IN	2,745,473	537	2,750	0.94					0.11	0.20
City of Anderson	IN	1,239,318	1,268	1,258	0.77					1.53	1.02
City of Columbus	IN	1,174,645	834	1,202	0.74					0.61	0.71
City of East Chicago	IN	581,096	409	581	0.78					0.38	0.70
City of Kokomo	IN	1,948,348	1,087	2,016	0.23					2.19	0.56
City of La Porte	IN	730,119	206	739						0.28	0.28
City of Michigan	IN	769,232	1,083	779						1.41	1.41
City of Terre Haute	IN	511,039	867	514	1.65					1.94	1.70
City of Valparaiso	IN	698,058	634	698	0.51						0.91
Fort Wayne Public Transportation Corporation	IN	5,774,841	1,289	5,892	0.21					0.34	0.22
Gary Public Transportation Corporation	IN	1,067,049	2,821	1,067	2.55					3.81	2.64
Greater Lafayette Public Transportation Corporation	IN	11,912,461	5,685	13,023	0.47					1.34	0.48
Hamilton County Express Public Transit	IN	1,088,814	737	1,089						0.68	0.68

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					Transit Vehicle GHG Emissions per Passenger Mile (kg CO_2e)						
Transit Agency Name	**State**	**Passenger Miles**	**Transit Vehicle GHG Emissions (MT CO_2e)**	**Transportation and Land Use Efficiency GHG Savings (MT CO_2e)**	**Bus**	**Commuter Rail**	**Ferry**	**Heavy Rail**	**Light Rail**	**Van**	**All Transit Modes**
Hancock Area Rural Transit	IN	400,253	267	400						0.67	0.67
Indianapolis and Marion County Public Transportation	IN	45,589,009	28,493	47,146	0.56					1.40	0.63
LINK Hendricks County	IN	392,694	575	393						1.46	1.46
Metropolitan Evansville Transit System	IN	5,562,383	3,256	5,712	0.46					2.15	0.59
Michiana Area Council of Governments	IN	2,648,357	1,692	2,702	0.57					1.46	0.64
Muncie Indiana Transit System	IN	4,810,538	1,018	5,100	0.14					1.55	0.21
North Township of Lake County	IN	309,890	145	310						0.47	0.47
Northern Indiana Commuter Transportation District	IN	110,846,664	11,709	112,358		0.11					0.11
Opportunity Enterprises, Inc.	IN	1,559,228	586	1,559						0.38	0.38
Porter County Aging and Community Services, Inc.	IN	404,689	320	405						0.79	0.79
South Bend Public Transportation Corporation	IN	4,999,571	3,342	5,099	0.62					1.01	0.67
South Lake County Community Services, Inc.	IN	771,294	504	771						0.65	0.65
Butler, County of	KS	330,058	120	330						0.36	0.36
City of Derby	KS	192,304	40	192						0.21	0.21
City of Lawrence	KS	3,687,336	3,505	3,861	0.70					3.04	0.95
City of Wichita	KS	8,196,704	5,821	8,353	0.62					1.56	0.71
Flint Hills Area Transportation	KS	1,553,174	1,008	1,602						0.65	0.65
Johnson County	KS	8,000,086	5,967	8,043	0.66					2.62	0.75

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Transit Agency Name	**State**	**Passenger Miles**	**Transit Vehicle GHG Emissions (MT CO_2e)**	**Transportation and Land Use Efficiency GHG Savings (MT CO_2e)**	**Bus**	**Commuter Rail**	**Ferry**	**Heavy Rail**	**Light Rail**	**Van**	**All Transit Modes**
Topeka Metropolitan Transit Authority	KS	5,170,096	2,697	5,369	0.47					3.30	0.52
Unified Government of Wyandotte County and Kansas City	KS	1,247,760	477	1,249						0.38	0.38
University of Kansas	KS	1,608,066	883	1,640	0.55						0.55
Audubon Area Community Services, Inc.	KY	1,926,639	2,502	1,940						1.30	1.30
City of Ashland	KY	704,400	506	707	0.09					1.86	0.72
City of Henderson	KY	641,934	396	644	0.38					1.17	0.62
City of Owensboro	KY	1,055,651	1,079	1,073	1.02						1.02
Community Action of Southern Kentucky	KY	528,756	529	533						1.00	1.00
Kentuckiana Regional Planning and Development Agency	KY	6,339,543	904	6,384						0.14	0.14
Lexington Transit Authority	KY	20,255,982	10,572	21,878	0.42					1.22	0.52
Oldham's Public Bus	KY	65,215	46	65						0.70	0.70
Transit Authority of Central Kentucky	KY	3,771,853	1,932	3,991	0.13					0.59	0.51
Transit Authority of Northern Kentucky	KY	21,165,360	11,674	21,467	0.50					1.67	0.55
Transit Authority of River City	KY	50,091,723	25,729	53,013	0.44					1.52	0.51
Capital Area Transit System	LA	15,178,347	10,623	15,609	0.66					1.30	0.70
City of Alexandria	LA	2,563,524	1,619	2,652	0.50					1.66	0.63
City of Lake Charles	LA	1,197,675	553	1,209	0.40					1.30	0.46
City of Monroe	LA	3,885,335	823	4,030	0.17					1.18	0.21
City of Shreveport	LA	16,364,219	6,930	17,383	0.39					1.35	0.42
Jefferson Parish	LA	10,084,094	2,377	10,207	0.16					1.77	0.24

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Transit Agency Name	**State**	**Passenger Miles**	**Transit Vehicle GHG Emissions (MT CO_2e)**	**Transportation and Land Use Efficiency GHG Savings (MT CO_2e)**	**Bus**	**Commuter Rail**	**Ferry**	**Heavy Rail**	**Light Rail**	**Van**	**All Transit Modes**
Lafayette City-Parish Consolidated Government	LA	8,549,140	3,082	8,872	0.34					0.70	0.36
New Orleans Regional Transit Authority	LA	56,133,725	14,266	60,130	0.17		5.78		0.13	1.49	0.25
Plaquemines Parish Government	LA	778,880	3,830	779			10.29			0.38	4.92
River Parishes Transit Authority	LA	318,271	324	318						1.02	1.02
St. Bernard Parish	LA	367,882	421	368	1.14						1.14
St. Martin, Iberia, Lafayette Community Action Agency	LA	343,556	488	344						1.42	1.42
St. Tammany Parish Government	LA	1,239,752	679	1,249						0.20	0.55
Tangipahoa Voluntary Council on Aging	LA	596,731	334	602						0.56	0.56
Terrebonne Parish Consolidated Government	LA	703,326	1,170	707	1.49					3.20	1.66
Berkshire Regional Transit Authority	MA	5,228,330	2,266	5,766	0.35					1.51	0.43
Blooms Bus Lines, Inc.	MA	251,452	2,384	251	9.48						9.48
Brockton Area Transit Authority	MA	18,836,714	4,941	18,927	0.22					1.12	0.26
Cape Ann Transportation Authority	MA	883,891	711	884	0.61					1.97	0.80
Cape Cod Regional Transit Authority	MA	11,856,060	4,198	12,500	0.15					0.84	0.35
City of Beverly	MA	58,219	153	58						2.63	2.63
City of Burlington	MA	51,490	56	51						1.08	1.08
Greater Attleboro-Taunton Regional Transit Authority	MA	5,454,502	5,292	5,459	0.82					1.30	0.97
LimoLiner LLC	MA	4,116	44	4	10.68						10.68

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					Transit Vehicle GHG Emissions per Passenger Mile (kg CO_2e)						
Transit Agency Name	**State**	**Passenger Miles**	**Transit Vehicle GHG Emissions (MT CO_2e)**	**Transportation and Land Use Efficiency GHG Savings (MT CO_2e)**	**Bus**	**Commuter Rail**	**Ferry**	**Heavy Rail**	**Light Rail**	**Van**	**All Transit Modes**
Lowell Regional Transit Authority	MA	7,447,030	4,524	7,460	0.53					1.42	0.61
Massachusetts Bay Transportation Authority	MA	1,717,994,263	359,812	2,381,898	0.33	0.25	1.06	0.09	0.09	1.41	0.21
Merrimack Valley Regional Transit Authority	MA	10,786,065	5,962	10,815	0.47					2.02	0.55
MetroWest Regional Transit Authority	MA	4,334,190	3,773	4,338	0.78					1.09	0.87
Mission Hill Link, Inc.	MA	46,872	19	47						0.40	0.40
Montachusett Regional Transit Authority	MA	7,296,136	5,124	7,307	0.64					0.73	0.70
Peter Pan Bus Lines	MA	937,480	3,330	938	3.55						3.55
Pioneer Valley Transit Authority	MA	41,213,664	19,673	44,342	0.40					1.42	0.48
Southeastern Regional Transit Authority	MA	8,914,527	5,653	8,978	0.55					2.24	0.63
Town of Bedford	MA	20,838	17	21						0.82	0.82
Town of Lexington	MA	255,301	164	255						0.64	0.64
Woods Hole, Martha's Vineyard and Nantucket Steamship Authority	MA	41,461,929	40,582	50,027	0.22		1.07				0.98
Worcester Regional Transit Authority	MA	13,871,419	6,121	14,311	0.37					1.64	0.44
Anne Arundel County	MD	2,354,158	2,425	2,356	0.58					1.85	1.03
Board of Commissioners of Allegany County	MD	654,646	700	664	0.98					1.24	1.07
Board of County Commissioners of Calvert County	MD	638,692	905	646	0.64					2.72	1.42
Cecil County Government – SSCT	MD	704,389	1,372	704						1.95	1.95

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Transit Agency Name	**State**	**Passenger Miles**	**Transit Vehicle GHG Emissions (MT CO_2e)**	**Transportation and Land Use Efficiency GHG Savings (MT CO_2e)**	**Bus**	**Commuter Rail**	**Ferry**	**Heavy Rail**	**Light Rail**	**Van**	**All Transit Modes**
City of Annapolis	MD	1,918,285	1,547	1,920	0.72					4.25	0.81
City of Baltimore	MD	4,600,766	1,401	4,611	0.29		0.80				0.30
County Commissioners of Charles County	MD	5,575,805	2,814	5,896	0.42					1.87	0.50
County of Howard	MD	6,432,967	6,828	6,452	0.95					2.00	1.06
Frederick County	MD	3,684,660	2,726	3,791	0.65					1.53	0.74
Harford County	MD	1,984,973	1,892	2,005	0.56					1.52	0.95
Maryland Transit Administration	MD	726,266,306	222,047	808,508	0.30	0.21		0.49	0.23	1.54	0.31
Montgomery County	MD	81,258,497	45,144	82,843	0.56						0.56
Prince George's County	MD	22,422,856	12,308	22,540	0.52					2.38	0.55
St. Mary's County Government	MD	1,936,489	2,728	2,008						1.41	1.41
The County Commissioners of Carroll County	MD	2,510,743	1,276	2,608						0.51	0.51
The Tri-County Council for the Lower Eastern Shore	MD	7,909,804	2,657	8,647	0.25					1.20	0.34
Washington County	MD	2,178,867	1,629	2,207						0.75	0.75
Biddeford-Saco-Old Orchard Beach Transit Committee Shuttle Bus	ME	1,479,641	1,349	1,491	0.91						0.91
Casco Bay Island Transit District	ME	4,018,914	2,960	4,106			0.74				0.74
City of Bangor	ME	3,277,848	1,605	3,477	0.46					1.97	0.49
City of South Portland	ME	1,106,558	645	1,113	0.58						0.58
Greater Portland Transit District	ME	6,733,632	3,790	6,982	0.56						0.56

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Transit Agency Name	**State**	**Passenger Miles**	**Transit Vehicle GHG Emissions (MT CO_2e)**	**Transportation and Land Use Efficiency GHG Savings (MT CO_2e)**	**Bus**	**Commuter Rail**	**Ferry**	**Heavy Rail**	**Light Rail**	**Van**	**All Transit Modes**
Lewiston-Auburn Transit Committee	ME	1,488,413	597	1,530	0.26					1.45	0.40
Regional Transportation Program, Inc.	ME	1,790,419	1,063	1,807						0.48	0.59
Western Maine Transportation Services, Inc.	ME	479,635	852	484	1.56					2.11	1.78
York County Community Action Corporation	ME	2,318,054	810	2,333						0.09	0.35
Ann Arbor Area Transportation Authority	MI	34,727,641	6,980	39,388	0.14					0.37	0.20
Bay Metropolitan Transit Authority	MI	3,682,422	2,143	3,900	0.52					1.03	0.58
Blue Water Area Transportation Commission	MI	8,918,979	5,285	9,991	0.43					0.70	0.59
Capital Area Transportation Authority	MI	31,303,627	13,258	34,965	0.33					1.07	0.42
Central County Transportation Authority	MI	12,448,673	6,728	13,290	0.46					1.05	0.54
City of Battle Creek	MI	2,097,145	1,629	2,159	0.75					0.88	0.78
City of Buchanan	MI	131,503	57	132						0.44	0.44
City of Detroit	MI	100,829,569	44,744	103,855	0.43					0.82	0.44
City of Jackson Transportation Authority	MI	1,498,509	1,434	1,526	0.83					2.32	0.96
City of Midland	MI	1,935,542	576	2,006						0.30	0.30
City of Niles	MI	509,238	244	510						0.48	0.48
County of Muskegon	MI	2,288,584	2,503	2,324	1.02					1.43	1.09
Detroit Transportation Corporation	MI	2,694,457	2,822	2,696					1.05		1.05
Enterprise Rideshare	MI	35,633,503	4,456	35,834						0.13	0.13

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Transit Agency Name	**State**	**Passenger Miles**	**Transit Vehicle GHG Emissions (MT CO_2e)**	**Transportation and Land Use Efficiency GHG Savings (MT CO_2e)**	**Bus**	**Commuter Rail**	**Ferry**	**Heavy Rail**	**Light Rail**	**Van**	**All Transit Modes**
Harbor Transit Multi-Modal Transportation System	MI	4,383,108	1,133	4,515						0.26	0.26
Interurban Transit Partnership	MI	40,273,549	21,766	41,548	0.54					0.55	0.54
Lake Erie Transportation Commission	MI	1,575,430	1,539	1,580	0.66					1.36	0.98
Livingston County Board of Commissioners	MI	2,541,632	1,516	2,601						0.60	0.60
M-1 Rail	MI	1,812,007	1,578	1,813					0.87		0.87
Macatawa Area Express Transportation Authority	MI	1,848,648	1,842	1,886	0.62					1.99	1.00
Mass Transportation Authority	MI	32,697,133	17,184	36,193	0.37					1.36	0.53
Midland County Board of Commissioners	MI	1,352,553	1,521	1,387						1.12	1.12
Saginaw Transit Authority Regional Service	MI	3,623,072	2,760	3,739	0.70					1.64	0.76
Suburban Mobility Authority for Regional Transportation	MI	79,234,010	34,593	81,092	0.39					1.69	0.44
Twin Cities Area Transportation Authority	MI	2,103,641	726	2,185						0.35	0.35
University of Michigan Parking and Transportation Services	MI	15,721,596	3,731	16,636	0.24						0.24
City of Mankato	MN	2,856,379	1,029	3,017	0.25					2.35	0.36
City of Maple Grove	MN	217,024	417	217	1.67					1.96	1.92
City of Moorhead	MN	2,063,734	1,396	2,090	0.66					1.41	0.68
City of Plymouth	MN	5,826,115	2,995	5,839	0.46					2.51	0.51
City of Rochester	MN	7,545,151	1,347	8,152	0.17					0.38	0.18

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Transit Agency Name	**State**	**Passenger Miles**	**Transit Vehicle GHG Emissions (MT CO_2e)**	**Transportation and Land Use Efficiency GHG Savings (MT CO_2e)**	**Bus**	**Commuter Rail**	**Ferry**	**Heavy Rail**	**Light Rail**	**Van**	**All Transit Modes**
Duluth Transit Authority	MN	11,151,556	6,396	12,356	0.54					2.74	0.57
Metro Mobility	MN	26,103,531	39,016	26,383						1.49	1.49
Metro Transit	MN	379,748,747	55,010	445,443	0.10	0.30			0.24		0.14
Metropolitan Council	MN	16,788,214	7,165	16,902	0.31					0.60	0.43
Minnesota Valley Transit Authority	MN	28,634,507	4,866	28,971	0.17						0.17
SouthWest Transit	MN	20,808,097	5,357	20,985	0.23					1.55	0.26
St. Cloud Metropolitan Transit Commission	MN	6,884,580	4,776	7,373	0.61					1.60	0.69
University of Minnesota Transit	MN	2,200,650	1,900	2,202	0.86					1.32	0.86
Bi-State Development Agency of the Missouri-Illinois Metropolitan District	MO	224,965,476	93,653	252,622	0.43				0.32	1.70	0.42
Cape Girardeau County Transit Authority	MO	2,701,208	1,842	2,857	0.03					0.74	0.68
City of Columbia	MO	3,363,302	1,588	3,464	0.34					1.93	0.47
City of Independence	MO	1,458,570	545	1,460						0.37	0.37
City of Jefferson	MO	1,818,165	1,197	1,881	0.95					0.35	0.66
City of Joplin	MO	1,088,129	497	1,104	0.17					0.63	0.46
City of Springfield	MO	5,897,730	3,229	6,038	0.51					2.24	0.55
City of St. Joseph	MO	1,736,793	2,282	1,778	1.31						1.31
Kansas City Area Transportation Authority	MO	48,852,409	29,656	50,229	0.57					0.97	0.61
Kansas City	MO	2,622,218	457	2,627					0.17		0.17
Southeast Missouri State University	MO	1,362,434	150	1,401						0.11	0.11
City of Hattiesburg	MS	414,850	790	417	2.55					0.16	1.90
City of Jackson	MS	1,306,672	4,304	1,312	3.95					1.74	3.29
MS Coast Transportation Authority	MS	7,521,063	3,309	7,574	0.80					0.23	0.44

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City of Billings	MT	2,197,217	1,912	2,244	0.80					1.36	0.87
Great Falls Transit District	MT	1,325,581	1,398	1,355	1.03					1.28	1.05
Missoula Urban Transportation District	MT	3,376,685	2,230	3,533	0.63					1.64	0.66
University of Montana	MT	456,558	225	459	0.49						0.49
Alamance County Transportation Authority	NC	1,337,152	1,178	1,353						0.88	0.88
Buncombe County	NC	1,340,845	1,528	1,348	0.77					1.25	1.14
Cabarrus County	NC	1,433,872	793	1,444						0.55	0.55
Cape Fear Public Transportation Authority	NC	4,265,371	4,105	4,357	0.91					1.32	0.96
City of Asheville	NC	5,317,151	2,579	5,428	0.49						0.49
City of Burlington	NC	426,103	343	428						0.80	0.80
City of Charlotte North Carolina	NC	116,204,351	42,773	125,094	0.45				0.14	0.45	0.37
City of Concord	NC	1,829,240	1,893	1,831	1.04					0.96	1.03
City of Durham	NC	23,085,560	12,224	24,840	0.44					1.54	0.53
City of Fayetteville	NC	6,201,569	4,526	6,338	0.65					1.55	0.73
City of Gastonia	NC	868,121	1,073	873	1.30					0.74	1.24
City of Greensboro	NC	9,778,499	10,368	10,120	0.85					1.91	1.06
City of Greenville	NC	1,806,570	936	1,837	0.52						0.52
City of High Point	NC	4,551,285	1,528	4,690	0.32					0.51	0.34
City of Jacksonville	NC	623,868	1,321	628						2.12	2.12
City of Raleigh	NC	18,793,227	4,244	19,234	0.23						0.23
City of Rocky Mount	NC	3,129,529	3,186	3,291	0.68					1.19	1.02
City of Salisbury	NC	603,159	461	605	0.77						0.77
City of Winston Salem	NC	10,137,546	7,579	10,429	0.63					1.29	0.75
Craven County	NC	940,094	694	959						0.74	0.74
Davidson County	NC	1,280,519	210	1,284						0.16	0.16
Gaston County	NC	1,762,168	894	1,782						0.51	0.51

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Transit Agency Name	**State**	**Passenger Miles**	**Transit Vehicle GHG Emissions (MT CO_2e)**	**Transportation and Land Use Efficiency GHG Savings (MT CO_2e)**	**Bus**	**Commuter Rail**	**Ferry**	**Heavy Rail**	**Light Rail**	**Van**	**All Transit Modes**
Goldsboro-Wayne Transportation Authority	NC	2,034,025	1,267	2,110	0.20					0.92	0.62
Guilford County	NC	858,706	623	860						0.73	0.73
Henderson County	NC	336,475	179	337						0.53	0.53
Hoke County	NC	1,021,186	500	1,025						0.49	0.49
Mecklenburg County	NC	665,591	812	666						1.22	1.22
Mountain Projects, Inc.	NC	557,460	427	559						0.77	0.77
North Carolina State University	NC	5,126,387	723	5,158	0.14						0.14
Onslow United Transit System	NC	1,500,435	844	1,524						0.56	0.56
Orange County	NC	697,171	819	698						1.17	1.17
Piedmont Authority for Regional Transportation	NC	19,871,073	3,835	20,312	0.49					0.06	0.19
Pitt County	NC	809,185	543	815						0.67	0.67
Research Triangle Regional Public Transportation Authority	NC	25,063,729	10,791	25,576	0.48					0.27	0.43
Rowan County	NC	1,409,031	1,002	1,419	1.48					0.67	0.71
The County of Iredell	NC	1,500,447	1,016	1,502						0.68	0.68
Town of Cary	NC	1,600,819	2,235	1,604	1.10					1.73	1.40
Town of Chapel Hill	NC	12,400,242	7,796	12,895	0.57					3.13	0.63
Union County	NC	1,288,539	1,111	1,290						0.86	0.86
Wake County	NC	2,477,989	2,739	2,483						1.11	1.11
Western Piedmont Regional Transit Authority	NC	1,777,456	1,961	1,778	0.95					1.23	1.10
Bis-Man Transit Board	ND	2,556,064	2,005	2,645	2.55					0.42	0.78
Cities Area Transit	ND	1,268,199	1,257	1,297	0.92					1.37	0.99
City of Fargo	ND	6,155,578	3,423	6,395	0.49					1.77	0.56
Fargo Park District	ND	899,322	341	904						0.38	0.38
City of Lincoln	NE	7,365,018	5,751	7,598	0.73					2.37	0.78

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					Transit Vehicle GHG Emissions per Passenger Mile (kg CO_2e)						
Transit Agency Name	**State**	**Passenger Miles**	**Transit Vehicle GHG Emissions (MT CO_2e)**	**Transportation and Land Use Efficiency GHG Savings (MT CO_2e)**	**Bus**	**Commuter Rail**	**Ferry**	**Heavy Rail**	**Light Rail**	**Van**	**All Transit Modes**
Nebraska Department of Transportation	NE	132,009	63	132						0.48	0.48
Senior Citizen Industries	NE	660,832	228	670						0.35	0.35
Transit Authority of Omaha	NE	13,340,436	12,034	13,611	0.86					1.66	0.90
Boston Express Bus, Inc.	NH	2,468,724	3,680	2,470	1.49						1.49
City of Nashua	NH	2,083,827	797	2,105	0.37					0.53	0.38
Cooperative Alliance for Seacoast Transportation	NH	3,455,463	1,959	3,530	0.51					2.16	0.57
Greater Derry Salem Cooperative Alliance for Regional Transportation	NH	251,313	216	251						0.86	0.86
Jalbert Leasing, Inc.	NH	3,133,521	7,758	3,133	2.48						2.48
Manchester Transit Authority	NH	1,832,405	1,555	1,856	0.87					0.60	0.85
University of New Hampshire	NH	4,465,743	1,382	4,591	0.28						0.31
A&C Bus Corporation & Montgomery & Westside Owners Association	NJ	16,626,088	2,116	16,640	0.13						0.13
Academy Lines, Inc.	NJ	151,141,079	21,867	152,489	0.14						0.14
Bergen County	NJ	1,631,345	1,728	1,631	0.44					1.16	1.06
Broadway Bus Corporation	NJ	3,011,955	383	3,012	0.13						0.13
Cape May County	NJ	1,876,351	958	1,953	18.14					0.47	0.51
Community Transit, Inc.	NJ	1,964,467	3,521	1,964	1.79						1.79
County of Atlantic	NJ	912,150	1,282	912						1.41	1.41
County of Burlington	NJ	303,530	665	303						2.19	2.19
County of Cumberland	NJ	269,912	221	270						0.82	0.82
County of Hunterdon	NJ	1,718,413	1,183	1,718						0.69	0.69
County of Mercer	NJ	1,874,444	841	1,885						0.45	0.45
Cumberland County	NJ	481,493	813	481						1.69	1.69
DeCamp Bus Lines	NJ	30,996,958	7,150	31,049	0.23						0.23

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					Transit Vehicle GHG Emissions per Passenger Mile (kg CO_2e)						
Transit Agency Name	**State**	**Passenger Miles**	**Transit Vehicle GHG Emissions (MT CO_2e)**	**Transportation and Land Use Efficiency GHG Savings (MT CO_2e)**	**Bus**	**Commuter Rail**	**Ferry**	**Heavy Rail**	**Light Rail**	**Van**	**All Transit Modes**
East Windsor Township	NJ	47,261	127	47	0.05						2.68
Gloucester County	NJ	441,183	257	441						0.58	0.58
Hudson Transit Lines, Inc.	NJ	196,203,402	28,339	198,436	0.14						0.14
Lakeland Bus Lines, Inc.	NJ	52,870,209	8,604	53,028	0.16						0.16
Meadowlands Transportation Brokerage Corporation	NJ	1,518,870	1,780	1,519						1.17	1.17
Middlesex County	NJ	3,506,840	1,436	3,507	0.31					0.63	0.41
Morris County Human Services	NJ	908,995	697	909						0.77	0.77
New Jersey Transit Corporation	NJ	3,402,633,641	656,380	3,943,964	0.27	0.14			0.16	0.76	0.19
Olympia Trails Bus Company, Inc.	NJ	2,313,236	2,347	2,313	1.01						1.01
Orange-Newark-Elizabeth, Inc.	NJ	16,781,260	5,614	16,795	0.33						0.33
Port Authority Trans-Hudson Corporation	NJ	448,342,660	43,367	460,486			2.23	0.08			0.10
Port Authority Transit Corporation	NJ	96,375,041	15,378	98,254				0.16			0.16
Port Imperial Ferry Corporation	NJ	25,685,026	30,853	25,720	0.49		1.41				1.20
Rockland Coaches, Inc.	NJ	50,090,570	9,173	50,232	0.18						0.18
Saddle River Trail, Inc.	NJ	757,063	906	757	1.20						1.20
Senior Citizens United Community Services of Camden County, Inc.	NJ	889,699	1,635	890						1.84	1.84
Somerset County	NJ	2,159,150	2,493	2,159	0.79					1.35	1.15
South Jersey Transportation Authority	NJ	771,954	932	772	0.08						1.21

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					Transit Vehicle GHG Emissions per Passenger Mile (kg CO_2e)						
Transit Agency Name	State	Passenger Miles	Transit Vehicle GHG Emissions (MT CO_2e)	Transportation and Land Use Efficiency GHG Savings (MT CO_2e)	Bus	Commuter Rail	Ferry	Heavy Rail	Light Rail	Van	All Transit Modes
Suburban Transit Corporation	NJ	93,829,030	12,118	94,341	0.13						0.13
City of Albuquerque Transit Department	NM	35,124,038	23,613	37,003	0.60					1.79	0.67
City of Farmington	NM	541,522	449	548	0.03					5.14	0.83
City of Las Cruces	NM	3,207,661	1,915	3,296	0.61					0.57	0.60
City of Santa Fe	NM	3,227,227	2,826	3,358	0.80					2.30	0.88
North Central Regional Transit District	NM	1,349,487	2,829	1,372	0.35					9.61	2.10
Rio Metro Regional Transit District	NM	37,843,042	14,030	39,644	0.60	0.34				1.63	0.37
South Central Regional Transit District	NM	122,870	363	123						2.96	2.96
Zia Therapy Center, Inc.	NM	575,302	911	578	0.04					6.59	1.58
Carson Area Metropolitan Planning Organization	NV	1,282,769	688	1,314	0.65					0.35	0.54
Regional Transportation Commission of Southern Nevada	NV	258,916,863	74,754	301,660	0.22					1.44	0.29
Regional Transportation Commission of Washoe County	NV	38,762,545	7,114	42,635	0.13					0.26	0.18
Tahoe Transportation District	NV	2,332,028	1,913	2,334	0.78					1.49	0.82
Adirondack Transit Lines, Inc,	NY	41,046,163	5,912	41,134	0.14						0.14
BillyBey Ferry Company, LLC	NY	3,728,167	9,813	3,728			2.63				2.63
Broome County	NY	7,652,374	4,547	8,071	0.51					1.50	0.59
Capital District Transportation Authority	NY	60,862,053	28,238	67,411	0.38					3.17	0.46

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					Transit Vehicle GHG Emissions per Passenger Mile (kg CO_2e)						
Transit Agency Name	**State**	**Passenger Miles**	**Transit Vehicle GHG Emissions (MT CO_2e)**	**Transportation and Land Use Efficiency GHG Savings (MT CO_2e)**	**Bus**	**Commuter Rail**	**Ferry**	**Heavy Rail**	**Light Rail**	**Van**	**All Transit Modes**
Central New York Regional Transportation Authority	NY	34,972,372	18,124	37,614	0.47					2.02	0.52
Chemung County	NY	2,550,649	1,646	2,610	0.71					0.34	0.65
City of Glens Falls	NY	1,268,101	793	1,295	0.64					0.22	0.63
City of Kingston	NY	338,176	412	340	1.00					2.98	1.22
City of Long Beach	NY	625,929	896	626	1.36					2.26	1.43
City of Mechanicville	NY	20,566	14	21						0.70	0.70
City of Watertown	NY	585,862	346	592	0.62					0.49	0.59
County of Nassau	NY	129,518,992	46,494	130,504	0.35					0.91	0.36
County of Rockland	NY	16,064,159	8,923	16,077	0.52					1.64	0.56
Dutchess County	NY	4,356,678	3,878	4,405	0.81					2.97	0.89
Hampton Jitney, Inc.	NY	73,791,820	7,631	74,105	0.10						0.10
Kaser Bus Service	NY	127,594	287	128	2.25						2.25
Leprechaun Lines, Inc.	NY	124,677	1,213	125	9.73						9.73
Metro-North Commuter Railroad Company, dba MTA Metro-North Railroad	NY	2,155,676,318	230,398	2,420,476	1.39	0.11	3.36				0.11
Monroe Bus Corporation	NY	17,875,468	1,734	17,891	0.10						0.10
Monsey New Square Trails Corporation	NY	25,869,858	4,358	25,904	0.17						0.17
MTA Bus Company	NY	381,346,415	150,337	390,100	0.39						0.39
MTA Long Island Rail Road	NY	3,405,961,936	238,811	4,192,875		0.07					0.07
MTA New York City Transit	NY	11,721,684,766	1,038,772	25,580,668	0.28			0.05		1.43	0.09
New York City Department of Transportation	NY	144,028,664	60,092	145,251	0.19		0.45				0.42
New York City Economic Development Corporation	NY	22,278,258	24,648	22,304			1.11				1.11
Newburgh Beacon Bus Corporation	NY	586,790	701	588	0.88						1.20
Niagara Frontier Transportation Authority	NY	87,339,282	30,605	96,843	0.36				0.10	1.46	0.35

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					Transit Vehicle GHG Emissions per Passenger Mile (kg CO_2e)						
Transit Agency Name	**State**	**Passenger Miles**	**Transit Vehicle GHG Emissions (MT CO_2e)**	**Transportation and Land Use Efficiency GHG Savings (MT CO_2e)**	**Bus**	**Commuter Rail**	**Ferry**	**Heavy Rail**	**Light Rail**	**Van**	**All Transit Modes**
Orange County	NY	442,598	177	443						0.40	0.40
Putnam County	NY	986,707	1,051	987	0.97					1.60	1.06
Regional Transit Service – Monroe County	NY	52,181,810	20,950	56,525	0.36					1.60	0.40
Staten Island Rapid Transit Operating Authority	NY	50,703,762	7,634	50,849				0.15			0.15
Suffolk County	NY	37,272,797	33,196	37,349	0.66					1.56	0.89
Tompkins Consolidated Area Transit	NY	12,125,152	6,145	15,639	0.47					1.29	0.51
Town of Clarkstown	NY	461,622	976	462						2.11	2.11
Town of Highlands	NY	83,938	20	84						0.24	0.24
Town of Huntington	NY	818,294	1,125	818	1.26					1.55	1.38
Town of Monroe	NY	495,698	132	496						0.27	0.27
Town of Newburgh	NY	79,048	53	79						0.67	0.67
Town of Warwick	NY	334,403	163	335						0.49	0.49
Ulster County	NY	3,694,315	1,485	3,725	0.33					3.22	0.40
Village of Kiryas Joel	NY	591,667	253	592	0.43						0.43
Village of Spring Valley	NY	26,444	63	26						2.37	2.37
Westchester County	NY	122,024,131	42,415	122,897	0.33					1.17	0.35
Board of Clermont County Commissioners	OH	1,879,506	1,745	1,882	0.54					1.25	0.93
Butler County Regional Transit Authority	OH	1,771,436	2,013	1,773	0.97					2.50	1.14
Central Ohio Transit Authority	OH	76,648,824	49,741	81,528	0.61					1.51	0.65
City of Middletown	OH	652,284	535	657	0.83					0.73	0.82
City of Shelby	OH	73,897	15	74						0.20	0.20
City of Springfield	OH	816,083	793	825	0.37					5.08	0.97
County of Warren	OH	600,991	563	601						0.94	0.94
Delaware County Transit Board	OH	391,006	770	391	1.56					2.70	1.97

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					Transit Vehicle GHG Emissions per Passenger Mile (kg CO_2e)						
Transit Agency Name	**State**	**Passenger Miles**	**Transit Vehicle GHG Emissions (MT CO_2e)**	**Transportation and Land Use Efficiency GHG Savings (MT CO_2e)**	**Bus**	**Commuter Rail**	**Ferry**	**Heavy Rail**	**Light Rail**	**Van**	**All Transit Modes**
Greater Dayton Regional Transit Authority	OH	55,723,338	22,414	60,667	0.33					2.30	0.40
Greene County Transit Board	OH	1,823,104	1,893	1,828						1.04	1.04
Laketran	OH	7,866,539	5,562	7,903	0.45					1.23	0.71
Lawrence County Port Authority	OH	189,255	302	189						1.59	1.59
Licking County	OH	1,470,529	1,984	1,472						1.35	1.35
Lima Allen County Regional Transit Authority	OH	1,612,025	950	1,651	0.75					0.43	0.59
Lorain County	OH	693,914	674	694						0.97	0.97
Medina County Public Transit	OH	640,488	787	641	1.12					1.31	1.23
METRO Regional Transit Authority	OH	23,079,221	17,166	23,299	0.65					1.89	0.74
Miami County	OH	381,182	705	381						1.85	1.85
Mid-Ohio Regional Planning Commission	OH	3,164,097	385	3,168						0.12	0.12
Portage Area Regional Transportation Authority	OH	3,696,544	3,378	3,702	0.76					1.58	0.91
Richland County Transit	OH	1,152,696	723	1,172	0.78					0.06	0.63
Southwest Ohio Regional Transit Authority	OH	85,106,562	37,395	90,158	0.42				0.73	0.91	0.44
Stark Area Regional Transit Authority	OH	16,799,888	8,273	16,915	0.38					1.73	0.49
Steel Valley Regional Transit Authority	OH	853,031	329	864						0.39	0.39
The Greater Cleveland Regional Transit Authority	OH	164,600,139	70,090	177,827	0.42			0.25	0.81	1.31	0.43
Toledo Area Regional Transit Authority	OH	12,206,994	3,990	12,532	0.32					0.36	0.33

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					Transit Vehicle GHG Emissions per Passenger Mile (kg CO_2e)						
Transit Agency Name	**State**	**Passenger Miles**	**Transit Vehicle GHG Emissions (MT CO_2e)**	**Transportation and Land Use Efficiency GHG Savings (MT CO_2e)**	**Bus**	**Commuter Rail**	**Ferry**	**Heavy Rail**	**Light Rail**	**Van**	**All Transit Modes**
Western Reserve Transit Authority	OH	6,179,157	3,916	6,287	0.58					1.51	0.63
Central Oklahoma Transportation and Parking Authority	OK	15,409,491	8,198	15,713	0.49		2.73			1.51	0.53
City of Edmond	OK	996,190	612	997	0.43					1.50	0.61
City of Lawton	OK	1,621,950	1,576	1,653	0.95					1.11	0.97
Metropolitan Tulsa Transit Authority	OK	15,706,533	8,832	16,124	0.43					2.80	0.56
University of Oklahoma	OK	5,206,598	2,833	5,502	0.32					2.29	0.54
Benton County	OR	1,502,176	1,306	1,542	0.30					0.88	0.87
Central Oregon Intergovernmental Council	OR	4,799,953	2,118	5,113	0.32					2.32	0.44
City of Albany	OR	1,077,195	728	1,088	0.80					0.42	0.68
City of Corvallis	OR	3,638,715	349	3,880	0.10						0.10
City of Milton-Freewater	OR	19,954	33	20						1.65	1.65
City of Portland	OR	10,171,647	833	10,231					0.08		0.08
City of Wilsonville	OR	2,148,758	1,133	2,151	0.49					1.14	0.53
Josephine County	OR	1,121,845	691	1,149	0.62					0.61	0.62
Lane Transit District	OR	39,309,964	13,433	43,001	0.32					0.52	0.34
Ride Connection, Inc.	OR	544,311	693	544	0.98					1.75	1.27
Rogue Valley Transportation District	OR	6,868,264	3,094	7,213	0.39					1.49	0.45
Salem Area Mass Transit District	OR	15,421,986	8,878	15,545	0.47					0.73	0.58
Tri-County Metropolitan Transportation District of Oregon	OR	425,745,833	40,151	551,794	0.10	0.11			0.08	0.35	0.09
Airport Corridor Transportation Association	PA	1,451,246	231	1,452						0.16	0.16
Altoona Metro Transit	PA	2,487,900	1,819	2,574	0.71					1.70	0.73

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Transit Agency Name	**State**	**Passenger Miles**	**Transit Vehicle GHG Emissions (MT CO_2e)**	**Transportation and Land Use Efficiency GHG Savings (MT CO_2e)**	**Bus**	**Commuter Rail**	**Ferry**	**Heavy Rail**	**Light Rail**	**Van**	**All Transit Modes**
Beaver County Transit Authority	PA	10,367,679	3,843	10,434	0.31					1.03	0.37
Borough of Pottstown	PA	282,716	931	283	3.38					1.70	3.29
Butler Transit Authority	PA	893,304	694	894	0.78						0.78
Cambria County Transit Authority	PA	4,266,769	3,514	4,568	0.80				3.63	0.89	0.82
Central Pennsylvania Transportation Authority	PA	16,211,812	13,709	16,294	0.58					1.10	0.85
Centre Area Transportation Authority	PA	23,899,720	7,393	32,582	0.38					0.14	0.31
City of Hazleton	PA	906,618	1,130	923	1.27					1.09	1.25
City of Sharon	PA	1,942,716	1,518	1,953	1.30					0.67	0.78
City of Williamsport	PA	6,441,206	2,655	7,316	0.41					1.57	0.41
County of Carbon	PA	844,506	776	846						0.92	0.92
County of Fayette	PA	3,056,318	2,702	3,062	0.85					0.91	0.88
County of Lackawanna Transit System	PA	5,567,021	4,964	5,656	0.57					2.71	0.89
County of Lebanon Transit Authority	PA	2,188,748	1,665	2,194	0.67					1.19	0.76
Cumberland Dauphin-Harrisburg Transit Authority	PA	12,295,902	9,112	12,674	0.59					1.71	0.74
Erie Metropolitan Transit Authority	PA	9,803,214	8,664	10,356	0.76					1.65	0.88
Lehigh and Northampton Transportation Authority	PA	26,254,602	14,148	27,419	0.45					1.01	0.54
Luzerne County Transportation Authority	PA	6,297,466	4,959	6,412	0.69					1.15	0.79
Mid Mon Valley Transit Authority	PA	4,330,659	2,098	4,341	0.48					2.04	0.48
Monroe County Transportation Authority	PA	3,492,565	3,047	3,494	0.65					1.16	0.87

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Transit Agency Name	**State**	**Passenger Miles**	**Transit Vehicle GHG Emissions (MT CO_2e)**	**Transportation and Land Use Efficiency GHG Savings (MT CO_2e)**	**Bus**	**Commuter Rail**	**Ferry**	**Heavy Rail**	**Light Rail**	**Van**	**All Transit Modes**
Port Authority of Allegheny County	PA	267,132,134	115,446	317,217	0.37				0.58	1.26	0.43
South Central Transit Authority	PA	25,740,458	9,056	26,852	0.13					1.23	0.35
Southeastern Pennsylvania Transportation Authority	PA	1,330,519,510	205,369	1,719,336	0.11	0.16		0.13	0.16	2.23	0.15
Southwestern Pennsylvania Commission	PA	5,605,226	675	5,624						0.12	0.12
Trans-Bridge Lines, Inc.	PA	79,839,496	8,502	80,194	0.11						0.11
Washington County Transportation Authority	PA	3,141,485	3,558	3,147	0.63					1.45	1.13
Westmoreland County	PA	6,495,222	3,419	6,521	0.53						0.53
Alternativa de Transporte Integrado – ATI	PR	22,741,894	5,920	23,004	0.71			0.16			0.26
Autonomous Municipality of Ponce	PR	1,873,372	408	1,899	0.22					0.17	0.22
City of San Juan	PR	1,636,879	333	1,638	0.17						0.20
Metropolitan Bus Authority	PR	20,892,652	13,614	21,113	0.63					1.41	0.65
Municipality of Aguada	PR	27,453	25	27						0.92	0.92
Municipality of Barceloneta	PR	274,125	256	275	0.68					2.10	0.93
Municipality of Bayamon	PR	1,081,147	313	1,082	0.28					0.42	0.29
Municipality of Caguas	PR	772,472	298	773	0.20					2.16	0.39
Municipality of Camuy	PR	104,123	124	104	0.52					1.75	1.19
Municipality of Carolina	PR	2,064,370	758	2,066	0.34					1.99	0.37
Municipality of Catano	PR	24,671	9	25	0.21					0.63	0.36
Municipality of Cayey	PR	178,647	96	179	0.26					1.74	0.54
Municipality of Dorado	PR	293,474	225	293	0.82					0.44	0.77
Municipality of Fajardo	PR	377,193	64	379	0.25					0.11	0.17
Municipality of Guaynabo	PR	1,273,115	512	1,274	0.34					3.14	0.40
Municipality of Gurabo	PR	70,172	51	70	0.58					1.50	0.73
Municipality of Hatillo	PR	39,747	61	40	1.58					1.52	1.53

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Transit Agency Name	State	Passenger Miles	Transit Vehicle GHG Emissions (MT CO_2e)	Transportation and Land Use Efficiency GHG Savings (MT CO_2e)	Bus	Commuter Rail	Ferry	Heavy Rail	Light Rail	Van	All Transit Modes
Municipality of Hormigueros	PR	191,454	80	192						0.42	0.42
Municipality of Humacao	PR	392,704	48	393	0.19					0.10	0.12
Municipality of Juncos	PR	211,950	56	212	0.10					1.59	0.26
Municipality of Lares	PR	66,775	119	67	0.83					4.23	1.78
Municipality of Manati	PR	120,631	115	121						0.96	0.96
Municipality of Mayaguez	PR	630,600	461	634	0.03					27.00	0.73
Municipality of San Lorenzo	PR	382,539	644	383	1.90					1.17	1.68
Municipality of San Sebastian	PR	59,787	151	60	0.81					3.69	2.53
Municipality of Toa Baja	PR	399,805	314	400	0.29					2.01	0.78
Municipality of Vega Baja	PR	313,160	173	313	0.36					0.76	0.55
Municipality of Yauco	PR	526,638	483	530	0.38					2.39	0.92
Puerto Rico Maritime Transport Authority	PR	11,287,502	22,967	11,348			2.03				2.03
Rhode Island Department of Transportation	RI	1,080,234	1,605	1,081			1.49				1.49
Rhode Island Public Transit Authority	RI	75,326,745	28,489	80,767	0.34					0.99	0.38
Berkeley Charleston Dorchester RTMA	SC	377,705	938	378						2.48	2.48
Central Midlands Regional Transportation Authority	SC	7,430,770	7,370	7,541	0.95					1.32	0.99
Charleston Area Regional Transportation Authority	SC	16,791,857	7,678	17,365	0.43					1.05	0.46
City of Anderson	SC	1,377,069	702	1,405	0.51						0.51
City of Clemson	SC	4,078,830	1,640	4,124	0.40						0.40
Greenville Transit Authority	SC	4,357,263	2,788	4,397	0.60					2.79	0.64
Lancaster County Council on Aging	SC	432,784	544	433						1.26	1.26
Lower Savannah COG	SC	269,522	165	270						0.61	0.61

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					Transit Vehicle GHG Emissions per Passenger Mile (kg CO_2e)						
Transit Agency Name	State	Passenger Miles	Transit Vehicle GHG Emissions (MT CO_2e)	Transportation and Land Use Efficiency GHG Savings (MT CO_2e)	Bus	Commuter Rail	Ferry	Heavy Rail	Light Rail	Van	All Transit Modes
Pee Dee Regional Transportation Authority	SC	1,028,741	2,018	1,042	1.65					17.63	1.96
Santee Wateree Regional Transportation Authority	SC	1,615,174	974	1,619	0.52					1.15	0.60
Spartanburg Regional Health Services, Inc.	SC	2,427,722	2,665	2,463						1.10	1.10
Spartanburg Transit System	SC	1,581,305	848	1,596	0.53						0.54
Waccamaw Regional Transportation Authority	SC	2,303,391	2,372	2,330	0.89					2.20	1.03
York County Council on Aging	SC	392,466	226	394						0.58	0.58
City of Rapid City	SD	2,960,095	1,437	3,081	0.15					0.83	0.49
Community Coordinated Transportation System	SD	411,080	161	412						0.39	0.39
Su Tran LLC dba: Sioux Area Metro	SD	3,934,928	2,695	4,044	0.56					1.32	0.68
Chattanooga Area Regional Transportation Authority	TN	8,598,596	7,520	8,813	0.85				0.11	2.03	0.87
City of Bristol Tennessee	TN	323,050	448	325	1.75					0.87	1.39
City of Clarksville	TN	3,300,081	3,929	3,376	1.23					1.01	1.19
City of Franklin	TN	693,681	479	694	0.01					0.97	0.69
City of Johnson City	TN	3,176,489	1,246	3,270	0.17					1.08	0.39
City of Kingsport	TN	908,272	555	917						0.61	0.61
City of Knoxville	TN	8,265,555	9,678	8,400	1.11					2.11	1.17
City of Memphis	TN	35,324,833	21,536	36,640	0.51				0.86	2.06	0.61
City of Murfreesboro	TN	940,522	363	948						0.39	0.39
East Tennessee Human Resource Agency, Inc.	TN	4,692,300	6,904	4,731						1.47	1.47
First Tennessee Human Resource Agency	TN	3,294,787	2,608	3,335						0.79	0.79
Jackson Transit Authority	TN	2,624,472	1,791	2,732	0.57					1.81	0.68

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					Transit Vehicle GHG Emissions per Passenger Mile (kg CO_2e)						
Transit Agency Name	**State**	**Passenger Miles**	**Transit Vehicle GHG Emissions (MT CO_2e)**	**Transportation and Land Use Efficiency GHG Savings (MT CO_2e)**	**Bus**	**Commuter Rail**	**Ferry**	**Heavy Rail**	**Light Rail**	**Van**	**All Transit Modes**
Knoxville-Knox County Community Action Committee	TN	2,034,819	2,422	2,043						1.19	1.19
Metropolitan Transit Authority	TN	46,869,142	28,366	49,110	0.52					1.63	0.61
Mid-Cumberland Human Resource Agency	TN	4,155,025	5,711	4,300						1.37	1.37
Regional Transportation Authority	TN	16,139,396	4,995	16,365	0.28	0.58				0.09	0.31
Shelby County Government	TN	870,580	398	871						0.46	0.46
Southeast Tennessee Human Resource Agency – Cleveland Urban Area Transit System Division	TN	919,883	516	934						0.56	0.56
The Transportation Management Association Group	TN	4,440,169	378	4,457						0.09	0.09
Alamo Area Council of Governments	TX	1,230,524	2,101	1,231						1.70	1.71
Brazos Transit District	TX	3,626,024	3,186	3,711	0.59					1.62	0.88
Capital Metropolitan Transportation Authority	TX	163,899,442	75,030	172,184	0.49	0.25				0.40	0.46
City of Abilene	TX	2,493,252	1,721	2,556	0.83					0.55	0.69
City of Amarillo	TX	2,106,049	2,978	2,131						1.41	1.41
City of Arlington	TX	320,855	466	321						1.45	1.45
City of Beaumont	TX	1,492,299	3,077	1,509	1.92					4.19	2.06
City of Brownsville	TX	12,504,691	4,268	12,685	0.32					2.43	0.34
City of Cleburne	TX	573,366	530	573						0.92	0.92
City of Conroe	TX	188,847	131	189						0.69	0.69
City of El Paso	TX	77,814,815	30,078	86,629	0.34					1.61	0.39
City of Galveston	TX	2,806,675	710	2,808	0.21					0.55	0.25

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					Transit Vehicle GHG Emissions per Passenger Mile (kg CO_2e)						
Transit Agency Name	**State**	**Passenger Miles**	**Transit Vehicle GHG Emissions (MT CO_2e)**	**Transportation and Land Use Efficiency GHG Savings (MT CO_2e)**	**Bus**	**Commuter Rail**	**Ferry**	**Heavy Rail**	**Light Rail**	**Van**	**All Transit Modes**
City of Grand Prairie	TX	922,353	301	922						0.33	0.33
City of Longview	TX	1,102,913	942	1,116	0.83					1.11	0.85
City of Lubbock	TX	9,007,376	7,088	9,391	0.70					1.85	0.79
City of McAllen	TX	2,700,435	1,607	2,711	0.59					0.64	0.60
City of Port Arthur	TX	634,542	831	637	1.44					1.16	1.31
City of Round Rock	TX	469,194	166	469						0.35	0.35
City of Tyler	TX	1,198,984	1,042	1,211	0.48					1.27	0.87
City of Waco	TX	5,092,845	2,843	5,260	0.45					1.63	0.56
City of Wichita Falls	TX	1,976,186	1,666	2,020	0.83						0.84
Community Services, Inc.	TX	948,563	518	949						0.55	0.55
Concho Valley Transit District	TX	2,709,500	2,057	2,797	0.47					1.04	0.76
Corpus Christi Regional Transportation Authority	TX	24,634,610	13,226	26,821	0.46					1.34	0.54
Dallas Area Rapid Transit	TX	419,838,357	168,370	455,277	0.68	0.44			0.24	0.43	0.40
Denton County Transportation Authority	TX	17,552,693	9,012	17,609	0.86	0.47				0.21	0.51
Fort Bend County	TX	6,999,056	3,020	7,009	0.33					0.72	0.43
Fort Worth Transportation Authority	TX	30,728,543	23,489	30,926	1.02					0.39	0.76
Golden Crescent Regional Planning Commission	TX	2,252,423	1,612	2,342	0.36					1.02	0.72
Hill Country Transit District	TX	4,523,362	4,338	4,596	0.60					1.47	0.96
Laredo Transit Management, Inc.	TX	9,560,460	7,074	9,996	0.71					1.91	0.74
Lower Rio Grande Valley Development Council	TX	6,384,393	2,675	6,435	0.41					0.62	0.42
McKinney Avenue Transit Authority	TX	664,326	116	664					0.17		0.17

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					Transit Vehicle GHG Emissions per Passenger Mile (kg CO_2e)						
Transit Agency Name	**State**	**Passenger Miles**	**Transit Vehicle GHG Emissions (MT CO_2e)**	**Transportation and Land Use Efficiency GHG Savings (MT CO_2e)**	**Bus**	**Commuter Rail**	**Ferry**	**Heavy Rail**	**Light Rail**	**Van**	**All Transit Modes**
Metropolitan Transit Authority of Harris County	TX	560,238,385	192,602	628,343	0.35				0.19	0.41	0.34
Midland-Odessa Urban Transit District	TX	2,072,834	2,518	2,092	1.35					0.98	1.21
Public Transit Services	TX	1,147,900	921	1,148						0.80	0.80
San Marcos Urban Transit District	TX	590,494	641	598	1.19					1.00	1.09
SPAN, Incorporated	TX	1,040,044	1,376	1,040						1.32	1.32
STAR Transit	TX	2,085,974	3,496	2,087	1.47					1.77	1.68
Texarkana Urban Transit District	TX	1,409,842	738	1,438	0.35					1.77	0.52
Texas State University	TX	5,652,555	2,726	6,365	0.48						0.48
Texoma Area Paratransit System, Inc	TX	512,320	794	517						1.55	1.55
The Gulf Coast Center	TX	1,773,839	1,410	1,774	0.74					1.04	0.79
The Woodlands Township	TX	20,340,653	3,235	20,425	0.16						0.16
VIA Metropolitan Transit	TX	183,291,462	91,400	195,545	0.53					0.40	0.50
Cache Valley Transit District	UT	4,986,849	2,465	5,284	0.45					2.07	0.49
City of St. George	UT	1,895,121	1,123	1,935	0.60					0.57	0.59
Utah Transit Authority	UT	358,146,681	103,688	435,421	0.54	0.25			0.14	0.19	0.29
Arlington County	VA	6,641,773	7,145	6,651	1.07					1.18	1.08
Central Shenandoah Planning District Commission	VA	1,158,963	772	1,185	0.07					6.43	0.67
City of Alexandria	VA	7,320,892	6,507	7,332	0.89						0.89
City of Bristol	VA	245,149	150	246						0.61	0.61
City of Charlottesville	VA	8,313,862	3,131	9,185	0.37						0.38
City of Fairfax	VA	2,052,265	1,072	2,053	0.52						0.52
City of Fredericksburg	VA	1,315,634	2,001	1,316						1.52	1.52

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					Transit Vehicle GHG Emissions per Passenger Mile (kg CO_2e)						
Transit Agency Name	**State**	**Passenger Miles**	**Transit Vehicle GHG Emissions (MT CO_2e)**	**Transportation and Land Use Efficiency GHG Savings (MT CO_2e)**	**Bus**	**Commuter Rail**	**Ferry**	**Heavy Rail**	**Light Rail**	**Van**	**All Transit Modes**
City of Harrisonburg Department of Public Transportation	VA	4,528,415	2,435	4,880	0.49					2.53	0.54
City of Petersburg	VA	1,528,086	1,811	1,531	0.95					2.95	1.19
City of Radford	VA	1,332,441	662	1,354	0.18						0.50
City of Suffolk	VA	470,037	339	470						0.72	0.72
City of Winchester	VA	769,263	409	779	0.36					0.87	0.53
District Three Governmental Cooperative	VA	2,914,034	793	3,051						0.27	0.27
Fairfax County	VA	41,656,872	30,518	42,067	0.73						0.73
Greater Lynchburg Transit Company	VA	10,225,148	3,447	11,266	0.30					2.41	0.34
Greater Richmond Transit Company	VA	62,680,034	23,814	63,270	0.52					0.25	0.38
Greater Roanoke Transit Company	VA	12,324,605	5,751	12,732	0.45					0.71	0.47
JAUNT, Inc.	VA	2,876,766	2,961	2,977						1.03	1.03
Loudoun County	VA	41,519,301	10,605	41,927	0.25					2.69	0.26
Potomac and Rappahannock Transportation Commission	VA	107,379,007	22,404	110,078	0.32					0.13	0.21
Town of Blacksburg	VA	6,971,379	3,664	7,605	0.49					3.30	0.53
Transportation District Commission of Hampton Roads	VA	73,738,183	38,007	77,793	0.48		1.68		0.26	0.93	0.52
Virginia Railway Express	VA	141,566,826	22,759	146,289		0.16					0.16
Williamsburg Area Transit Authority	VA	5,602,880	3,578	5,625	0.61					2.50	0.64
York County	VA	340,113	70	340	0.20						0.20
Virgin Islands Department of Public Works	VI	1,857,857	1,266	1,894	0.16					1.56	0.68

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					Transit Vehicle GHG Emissions per Passenger Mile (kg CO_2e)						
Transit Agency Name	State	Passenger Miles	Transit Vehicle GHG Emissions (MT CO_2e)	Transportation and Land Use Efficiency GHG Savings (MT CO_2e)	Bus	Commuter Rail	Ferry	Heavy Rail	Light Rail	Van	All Transit Modes
Green Mountain Transit Authority	VT	9,973,169	5,393	11,039	0.52					1.73	0.54
Asotin County	WA	806,540	490	820	0.47					0.68	0.61
Ben Franklin Transit	WA	32,817,347	13,432	39,036	0.76					0.29	0.41
Central Puget Sound Regional Transit Authority	WA	534,218,246	68,039	649,421	0.17	0.15			0.05		0.13
City of Everett	WA	7,538,575	5,259	7,558	0.57					1.99	0.70
City of Seattle	WA	1,819,602	193	1,820					0.11		0.11
City of Yakima	WA	7,006,235	2,843	7,436	0.50					0.24	0.41
Clark County Public Transportation Benefit Area Authority	WA	29,190,616	13,921	29,679	0.43					0.87	0.48
County of Pierce	WA	1,754,343	2,427	1,755			1.38				1.38
Intercity Transit	WA	37,295,807	12,386	37,765	0.51					0.18	0.33
King County Department of Metro Transit	WA	619,926,771	158,424	778,257	0.25		0.32		0.41	0.31	0.26
Kitsap Transit	WA	23,970,217	7,958	24,161	0.15		0.76			0.35	0.33
Link Transit	WA	10,911,266	3,757	13,079	0.33					1.09	0.34
Pierce County Transportation Benefit Area Authority	WA	60,433,981	24,931	61,751	0.47					0.32	0.41
RiverCities Transit	WA	1,679,244	687	1,728	0.18					2.49	0.41
Skagit Transit	WA	11,397,214	4,129	11,441	0.47					0.24	0.36
Snohomish County Public Transportation Benefit Area Corporation	WA	111,862,102	35,756	116,229	0.37					0.13	0.32
Spokane Transit Authority	WA	49,559,241	19,214	57,124	0.36					0.52	0.39
Valley Transit	WA	3,643,370	1,571	3,915	0.54					0.10	0.43
Washington State Ferries	WA	193,091,082	229,138	207,005			1.19				1.19
Whatcom Transportation Authority	WA	15,980,845	7,689	18,668	0.43					0.73	0.48

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					Transit Vehicle GHG Emissions per Passenger Mile (kg CO_2e)						
Transit Agency Name	State	Passenger Miles	Transit Vehicle GHG Emissions (MT CO_2e)	Transportation and Land Use Efficiency GHG Savings (MT CO_2e)	Bus	Commuter Rail	Ferry	Heavy Rail	Light Rail	Van	All Transit Modes
City of Appleton	WI	6,152,885	3,880	6,348	0.52					0.99	0.63
City of Beloit	WI	636,390	696	640	1.09						1.09
City of Chippewa Falls	WI	1,104,233	237	1,117						0.21	0.21
City of Eau Claire	WI	2,872,600	2,298	2,962	0.80					0.80	0.80
City of Green Bay	WI	4,038,921	3,578	4,126	0.83					1.65	0.89
City of Hartford	WI	330,687	74	332						0.23	0.23
City of Janesville	WI	2,210,324	1,313	2,251	0.59						0.59
City of Kenosha	WI	4,483,476	3,262	4,665	0.67				1.76	1.89	0.73
City of La Crosse	WI	2,992,342	1,947	3,091	0.64					0.92	0.65
City of Madison	WI	53,478,624	16,977	62,016	0.29					1.34	0.32
City of Milwaukee (*estimate due to missing data)	WI	160,893	1	161					0.01		0.01
City of Onalaska	WI	987,607	553	998						0.56	0.56
City of Oshkosh	WI	1,823,030	1,421	1,872	0.78						0.78
City of Racine	WI	4,678,867	3,959	4,693	0.82					1.70	0.85
City of Sheboygan	WI	3,034,532	2,128	3,180	0.66					0.87	0.70
City of Waukesha	WI	5,573,888	3,868	5,598	0.67					2.09	0.69
City of Wausau	WI	2,106,100	1,220	2,172	0.57					0.90	0.58
City of West Bend	WI	1,740,531	479	1,790						0.28	0.28
County of Washington	WI	3,380,581	2,102	3,389	0.37					1.22	0.62
Fond du Lac	WI	1,213,956	814	1,244	0.89					0.40	0.67
Milwaukee County	WI	109,817,303	50,751	119,938	0.43					1.66	0.46
Ozaukee County	WI	2,814,008	1,552	2,820	0.32					1.15	0.55
Eastern Panhandle Transit Authority	WV	1,159,739	1,251	1,168	0.37					2.77	1.08
Kanawha Valley Regional Transportation Authority	WV	8,174,058	5,773	8,669	0.68					1.52	0.71
Mid-Ohio Valley Transit Authority	WV	2,181,834	1,247	2,261	0.52					1.51	0.57

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					Transit Vehicle GHG Emissions per Passenger Mile (kg CO_2e)						
Transit Agency Name	**State**	**Passenger Miles**	**Transit Vehicle GHG Emissions (MT CO_2e)**	**Transportation and Land Use Efficiency GHG Savings (MT CO_2e)**	**Bus**	**Commuter Rail**	**Ferry**	**Heavy Rail**	**Light Rail**	**Van**	**All Transit Modes**
Monongalia County Urban Mass Transit Authority	WV	4,116,458	2,636	4,391	0.41					23.84	0.64
New River Transit Authority	WV	182,487	371	183						2.03	2.03
Ohio Valley Regional Transportation Authority	WV	1,287,072	3,574	1,309	2.77					3.31	2.78
The Tri-State Transit Authority	WV	4,977,698	3,136	5,113	0.52					3.19	0.63
Weirton Transit Corporation	WV	195,676	182	196	0.05						0.93
West Virginia University – Morgantown Personal Rapid Transit	WV	3,623,838	1,888	3,835					0.52		0.52
City of Casper	WY	1,457,275	780	1,494						0.54	0.54
The City of Cheyenne	WY	955,344	521	969						0.55	0.55
Total		53,971,428,864	12,324,182	75,409,986	0.36	0.15	1.00	0.08	0.15	0.64	0.23
Min		4,116	1	4	0.01	0.07	0.32	0.04	0.01	0.06	0.01
Max		11,721,684,766	1,038,772	25,580,668	18.14	0.88	18.69	0.49	3.63	27.00	10.68
Average		59,505,434	13,588	83,142	0.71	0.27	2.72	0.16	0.48	1.38	0.75
Median		2,672,867	1,809	2,706	0.52	0.23	1.38	0.15	0.23	1.13	0.61
Count		907	907	907	634	29	27	15	46	761	907

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Abbreviations

BTU	British Thermal Unit
CH_4	Methane
CO_2	Carbon Dioxide
CO_2(b)	Biogenic Carbon Dioxide
CO_2e	Carbon Dioxide Equivalent
COVID-19	Coronavirus Disease 2019
eGRID	Emissions and Generation Resource Integrated Database
GHG	Greenhouse Gas
GIS	Geographic Information System
GREET	The Greenhouse Gases, Regulated Emissions, and Energy Use in Technologies Model
GWP	Global Warming Potential
kg	Kilograms
kWh	Kilowatt Hour
MMT	Million Metric Tons
mpg	Miles per Gallon
MT	Metric Tons
N_2O	Nitrous Oxide
NHTS	National Household Travel Survey
NTD	National Transit Database
SEM	Structural Equation Modeling
SOV	Single Occupancy Vehicle
TAZ	Traffic Analysis Zone
TOD	Transit-Oriented Development
U.S. EPA UZA	United States Environmental Protection Agency Urbanized Area
VMT	Vehicle Miles Traveled

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Glossary

Biogenic Greenhouse Gas	Greenhouse gas emissions resulting from fuels sourced from plant matter and part of the natural carbon cycle. Biogenic carbon dioxide, CO_2(b), is often tracked separately from other greenhouse gas emissions.
Bus	Rubber-tired vehicle operating on roadways. For the purposes of this report, "bus" also includes the NTD modes of "bus rapid transit," "commuter bus," "publico," and "trolleybus."
Carbon Dioxide Equivalent	CO_2e is the sum of greenhouse gases weighted by their relative 100-year climate impact using global warming potentials.
Commuter Rail	Train service that is typically region wide. Commuter rail in the 2018 NTD was fueled by biodiesel, diesel, or electricity. For the purposes of this report, the mode type "commuter rail" also includes NTD modes "Alaska railroad" and "hybrid rail."
Direct GHG Emissions	The CO_2, CH_4, and N_2O emissions that occurred at the vehicle when fuel was consumed.
Electric Battery Bus	A fully electric bus that stores electricity in a battery pack and uses it to power the vehicle. In this report, an electric battery bus is not a hybrid electric vehicle.
Electric Propulsion Bus	A bus propelled by electricity through an overhead wire or other continuous external source; also called a "trolleybus."
Emissions Factor	The greenhouse gas emissions associated with a unit of activity—for example, carbon dioxide per gallon of gasoline.
Ferry/Ferryboat	Watercraft used as public transportation. Ferryboats in the 2018 NTD were fueled by biodiesel or diesel fuel.
Global Warming Potential	The energy absorbed by a greenhouse gas relative to carbon dioxide. This report uses 100-year GWPs of 28 for CH_4 and 265 for N_2O.
Greenhouse Gas	Gases creating the greenhouse effect, absorbing and emitting heat in the atmosphere.
Heavy Rail	An electric-powered train with high capacity.
Indirect GHG Emissions	The CO_2, CH_4, and N_2O emissions that occurred at the power plant when electricity was produced or in the process of producing hydrogen.

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An Update on Public Transportation's Impacts on Greenhouse Gas Emissions

Land Use Efficiency GHG Savings	The GHG emissions saved by the broader impact of transit on VMT in the community, such as through shorter trips and fewer personal vehicle trips (also called indirect effect).
Light Rail	A lower-capacity train powered by electricity. For the purposes of this report, the mode type light rail also includes NTD modes "cable car," "inclined plane," "monorail," "automated guideway," and "streetcar rail."
Mode Shift Factor	The share of public transit passenger miles that would have otherwise been personal vehicle miles, such as through driving, carpooling, ridehailing, or taking a taxi.
Occupancy	The number of passengers per vehicle seat.
Passenger Mile	One mile ridden by a public transit passenger.
Personal Vehicle	Automobiles and light trucks; for the purpose of this report, includes ridehailing and taxi vehicles for hire; also called "private automobile."
Ridehailing	A hired car for a single trip; also called "transportation network company"; examples are Uber and Lyft.
Transit Multiplier	The ratio of the total VMT reduction associated with transit, including (1) the direct impacts of avoided personal vehicle travel by transit passengers and (2) the indirect effects of avoided travel in the communities with transit due to factors such as shorter trips and fewer personal vehicle trips, divided by the VMT reduction associated with transit use alone.
Transit Vehicle Miles	The full distance a transit vehicle travels, including revenue and non-revenue miles.
Transportation Efficiency GHG Savings	The GHG emissions saved by passengers riding transit rather than using automobiles (also called "direct effect").
Upstream Emissions	The GHG emissions that occurred during fuel production and distribution; also called "well-to-pump" emissions.
Van	Rubber-tired vehicles operating on roadways and having smaller seating capacity than buses. The NTD describes vans as seating 8 to 18 passengers. For the purposes of this report, the mode type "van" also includes NTD modes "demand response" and "jitney" and may include smaller passenger vehicles.

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Abbreviations and acronyms used without definitions in TRB publications:

A4A	Airlines for America
AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FAST	Fixing America's Surface Transportation Act (2015)
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HMCRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
MAP-21	Moving Ahead for Progress in the 21st Century Act (2012)
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TDC	Transit Development Corporation
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S. DOT	United States Department of Transportation

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