Current Practices in Greenhouse Gas Emissions Savings from Transit

DETAILS

77 pages | | PAPERBACK
ISBN 978-0-309-14303-5 | DOI 10.17226/14385

AUTHORS

TCRP
SYNTHESIS 84

TRANSIT
COOPERATIVE
RESEARCH
PROGRAM

Current Practices in Greenhouse Gas Emissions Savings from Transit

Sponsored by
the Federal
Transit Administration

A Synthesis of Transit Practice

TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

TRANSIT COOPERATIVE RESEARCH PROGRAM

TCRP SYNTHESIS 84

Current Practices in Greenhouse Gas Emissions Savings from Transit

A Synthesis of Transit Practice

CONSULTANTS
FRANK GALLIVAN
ICF International
San Francisco, California
and
MICHAEL GRANT
ICF International
Fairfax, Virginia

SUBSCRIBER CATEGORIES
Energy • Environment • Public Transportation

Research Sponsored by the Federal Transit Administration in Cooperation with
the Transit Development Corporation

TRANSPORTATION RESEARCH BOARD

WASHINGTON, D.C.
2010
www.TRB.org

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, to adapt appropriate new technologies from other industries, and to 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 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 longstanding and successful National Cooperative Highway Research Program, undertakes research and other technical activities in response to the needs of transit service providers. The scope of TCRP includes a variety of 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 Academy of Sciences, 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) Committee.

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 Committee to formulate the research program by identifying the highest priority projects. As part of the evaluation, the TOPS Committee 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 impact if products fail to reach the intended audience, special emphasis is placed on disseminating TCRP results to the intended end 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.

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

TCRP SYNTHESIS 84

Project J-7, Topic SH-09
ISSN 1073-4880
ISBN 978-0-309-14303-5
Library of Congress Control Number 2009942375

COPYRIGHT INFORMATION

NOTICE

The project that is the subject of this report was a part of the Transit Cooperative Research Program conducted by the Transportation Research Board with the approval of the Governing Board of the National Research Council. Such approval reflects the Governing Board's judgment that the project concerned is appropriate with respect to both the purposes and resources of the National Research Council.

The members of the technical advisory panel selected to monitor this project and to review this report were chosen for recognized scholarly competence and with due consideration for the balance of disciplines appropriate to the project. The opinions and conclusions expressed or implied are those of the research agency that performed the research, and while they have been accepted as appropriate by the technical panel, they are not necessarily those of the Transportation Research Board, the Transit Development Corporation, the National Research Council, or the Federal Transit Administration of the U.S. Department of Transportation.

Each report is reviewed and accepted for publication by the technical panel according to procedures established and monitored by the Transportation Research Board Executive Committee and the Governing Board of the National Research Council.

The Transportation Research Board of The National Academies, the Transit Development Corporation, the National Research Council, and the Federal Transit Administration (sponsor of the Transit Cooperative Research Program) do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the clarity and completeness of the project reporting.

Published reports of the

TRANSIT COOPERATIVE RESEARCH PROGRAM

are available from:

Transportation Research Board
Business Office
500 Fifth Street, NW
Washington, DC 20001

and can be ordered through the Internet at:
http://www.national-academies.org/trb/bookstore

Printed in the United States of America

THE NATIONAL ACADEMIES

Advisers to the Nation on Science, Engineering, and Medicine

The **National Academy of Sciences** is a private, nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. On the authority of the charter granted to it by the Congress in 1863, the Academy has a mandate that requires it to advise the federal government on scientific and technical matters. Dr. Ralph J. Cicerone is president of the National Academy of Sciences.

The **National Academy of Engineering** was established in 1964, under the charter of the National Academy of Sciences, as a parallel organization of outstanding engineers. It is autonomous in its administration and in the selection of its members, sharing with the National Academy of Sciences the responsibility for advising the federal government. The National Academy of Engineering also sponsors engineering programs aimed at meeting national needs, encourages education and research, and recognizes the superior achievements of engineers. Dr. Charles M. Vest is president of the National Academy of Engineering.

The **Institute of Medicine** was established in 1970 by the National Academy of Sciences to secure the services of eminent members of appropriate professions in the examination of policy matters pertaining to the health of the public. The Institute acts under the responsibility given to the National Academy of Sciences by its congressional charter to be an adviser to the federal government and, on its own initiative, to identify issues of medical care, research, and education. Dr. Harvey V. Fineberg is president of the Institute of Medicine.

The **National Research Council** was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and advising the federal government. Functioning in accordance with general policies determined by the Academy, the Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The Council is administered jointly by both Academies and the Institute of Medicine. Dr. Ralph J. Cicerone and Dr. Charles M. Vest are chair and vice chair, respectively, of the National Research Council.

The **Transportation Research Board** is one of six major divisions of the National Research Council. The mission of the Transportation Research Board is to provide leadership in transportation innovation and progress through research and information exchange, conducted within a setting that is objective, interdisciplinary, and multimodal. The Board's varied activities annually engage about 7,000 engineers, scientists, and other transportation researchers and practitioners from the public and private sectors and academia, all of whom contribute their expertise in the public interest. The program is supported by state transportation departments, federal agencies including the component administrations of the U.S. Department of Transportation, and other organizations and individuals interested in the development of transportation. **www.TRB.org**

www.national-academies.org

Cover Figure: Metro Transit Go Greener initiative. *Source:* Metro Transit, Minneapolis/St.Paul, Minnesota.

FOREWORD

Transit administrators, engineers, and researchers often face problems for which information already exists, either in documented form or as undocumented experience and practice. This information may be fragmented, scattered, and unevaluated. As a consequence, full knowledge of what has been learned about a problem may not be brought to bear on its solution. Costly research findings may go unused, valuable experience may be overlooked, and due consideration may not be given to recommended practices for solving or alleviating the problem.

There is information on nearly every subject of concern to the transit industry. Much of it derives from research or from the work of practitioners faced with problems in their day-to-day work. To provide a systematic means for assembling and evaluating such useful information and to make it available to the entire transit community, the Transit Cooperative Research Program Oversight and Project Selection (TOPS) Committee authorized the Transportation Research Board to undertake a continuing study. This study, TCRP Project J-7, "Synthesis of Information Related to Transit Problems," searches out and synthesizes useful knowledge from all available sources and prepares concise, documented reports on specific topics. Reports from this endeavor constitute a TCRP report series, *Synthesis of Transit Practice*.

This synthesis series reports on current knowledge and practice, in a compact format, without the detailed directions usually found in handbooks or design manuals. Each report in the series provides a compendium of the best knowledge available on those measures found to be the most successful in resolving specific problems.

PREFACE

By Donna Vlasak
Senior Program Officer
Transportation Research Board

This synthesis describes the role of transit agencies in reducing greenhouse gas (GHG) emissions and catalogues the current practice of a sample of transit agencies. The purpose of this synthesis is to inform transit agencies on how their services and operations specifically impact GHG missions from transportation. Transportation is one of the largest sources of GHG emissions in the United States. Policymakers, planners, and transportation agencies are increasingly considering how the transportation sector can reduce its GHG emissions. This goal presents a complex challenge with no one single solution for transit agencies. They can contribute to this goal by increasing total ridership, boosting the numbers of passengers on individual trips, and reducing their use of energy from fossil-based sources. However, planning for and implementing strategies to reduce GHG emissions are still developing scenarios in the transit industry. Many transit agencies are struggling with how a goal to reduce GHG emissions can fit with their traditional planning objectives.

Research for this study included a literature review, a survey of 41 transit agencies (66% response rate), and interviews with three agencies. The agencies that responded to the survey were all implementing or planning to implement reduction strategies. Agency interviews were based on depth of agency experience with reducing GHG emissions and implementation of unique strategy types.

Frank Gallivan, ICF International, San Francisco, California, and Michael Grant, ICF International, Fairfax, Virginia, collected and synthesized the information and wrote the report, under the guidance of a panel of experts in the subject area. The members of the topic panel are acknowledged on the preceding page. This synthesis is an immediately useful document that records the practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As progress in research and practice continues, new knowledge will be added to that now at hand.

CONTENTS

CURRENT PRACTICES IN GREENHOUSE GAS EMISSIONS SAVINGS FROM TRANSIT

SUMMARY

Transit agencies have a key role to play in reducing the greenhouse gas (GHG) emissions that contribute to climate change. Buses, trains, vans, and ferries can move passengers using less fuel than private vehicles can. Less fuel used generally means fewer GHGs emitted. Most U.S. transit agencies are already helping to reduce GHG emissions just by operating their current services, but transit agencies can further reduce GHG emissions and achieve other important goals by implementing strategies to increase ridership and improve the efficiency of their operations.

This study describes the role of transit agencies in reducing GHG emissions and catalogs the current practices of a sample of agencies. Research for this study included a literature review, a survey of 62 transit agencies, with 41 responding (66%); and interviews with three agencies.

Climate change is the broadest environmental challenge of the 21st century. Consequences of climate change expected in the coming years include rising sea levels, increases in average temperatures, changes in patterns of precipitation, and increases in the intensity and frequency of severe weather. These climatic shifts may reduce crop yields, increase the risk of invasive species, exacerbate drought conditions, and threaten endangered species. The built environment is also at risk. Human settlements in coastal and low-lying areas are particularly vulnerable to changes in sea level and to storm and precipitation events. Increases in global concentrations of GHGs, largely the result of human activities, are the predominant cause of climate change. Transportation is one of the largest sources of GHG emissions in the United States.

Public transportation stands out as an important partial solution to the problem. Passenger travel in cars and trucks alone generates nearly two-thirds of transportation's GHG emissions in the United States. Public transportation can reduce these emissions by transporting passengers more efficiently than private vehicles can. Transit reduces GHG emissions in four principal ways. Transit displaces emissions from other modes by:

1. Reducing miles traveled in private vehicles;

2. Reducing on-road congestion, thereby reducing fuel burned when vehicles idle on congested roadways; and

3. Facilitating compact development patterns that lead to less GHG-intensive travel.

Transit agencies can also:

4. Reduce the emissions that they generate from their vehicles and facilities.

The net impact of transit on GHG emissions depends on the balance of emissions displaced and emissions released by vehicles and facilities. A crucial determinant of transit's net impact is the passenger load on individual transit services. Ridership on vehicles must

be high enough that more emissions are displaced from private travel than are emitted from the tailpipe of the transit vehicle. Balancing emissions produced and displaced, many transit agencies are already net reducers of GHG emissions. The U.S. transit industry as a whole produces an annual net reduction of GHG emissions roughly equivalent to emissions from all transportation in the state of Washington.

In addition to the benefits of their existing services, every transit agency surveyed is planning or implementing strategies that can further reduce GHG emissions. Interest in these strategies is widespread across agencies, and agencies are generally aware of the impact such strategies can have on GHG emissions. Types of strategies are as follows:

- *Expanding transit service* (*78% of respondents planning or implementing*)—Agencies can increase ridership by expanding route coverage, increasing service frequency, and extending operating hours. These strategies will reduce GHG emissions as long as displaced emissions are not outweighed by higher emissions from transit vehicles.
- *Increasing vehicle passenger loads* (*93% of respondents planning or implementing*)—Strategies that boost passenger loads allow agencies to increase the emissions they displace without increasing emissions from transit vehicles, and without substantial new capital and operating expenditures. These strategies include improving transit access, comfort, and safety; improving service speed and reliability; providing transit information, marketing, and incentives to use transit; and optimizing existing transit routes (which could include reducing service).
- *Reducing roadway congestion* (*88% of respondents planning or implementing*)—Most transit strategies that mitigate congestion are the same strategies that increase transit ridership. Some transit agencies are partnering with local, state, and federal governments to provide transit service targeted to reduce congestion on specific corridors.
- *Promoting compact development* (*70% of respondents planning or implementing*)—Transit agencies can promote compact development in specific nodes around transit stations and by contributing to local and regional development and planning processes. These types of strategies typically require cooperation with other local and regional agencies.
- *Alternative fuels and vehicle types* (*90% of respondents planning or implementing*)—Some alternative propulsion technologies emit fewer GHGs per mile of travel than do conventional vehicles. Agencies can purchase new vehicles that use alternative propulsion technologies. In some cases, alternative fuels can be used in existing vehicles.
- *Vehicle operations and maintenance* (*90% of respondents planning or implementing*)—Improvements to existing vehicles and changes to operating practices can increase the fuel economy of vehicles and thereby reduce GHG emissions.
- *Construction and maintenance* (*73% of respondents planning or implementing*)—Strategies that reduce emissions from construction and maintenance are those that reduce the use of virgin materials or reduce the use of fossil fuels in construction and maintenance processes.
- *Reducing emissions from facilities and nonrevenue vehicles* (*83%*)—Agencies can reduce the use of fossil-based energy in their facilities through a variety of energy-saving measures and by using electricity generated from renewable sources. Agencies can help employees reduce their own GHG emissions.

Analytical and planning processes related to GHG emissions are still nascent fields in the transit industry, and in the transportation industry as a whole. Major findings from the literature review and survey include the following:

- GHG emissions are still a peripheral concern for transit agencies. Less than half of survey respondents said that reducing GHG emissions was a principal factor in pursuing any given strategy. Increasing ridership, reducing costs, and complying with environmental regulations were generally more important factors. Agencies are unlikely to pursue strategies for the sole purpose of reducing GHG emissions, but many strategies that reduce GHG emissions have substantial co-benefits.

- Guidance on calculating GHG emissions displaced by transit is still under development. The most robust methodologies use separate calculations for emissions displaced by mode shift, reduced congestion, and compact development. APTA's "Recommended Practice for Quantifying Greenhouse Gas Emissions from Transit" is the first analytical guidance issued for transit agencies. There is particular uncertainty around techniques to estimate the impact of transit on compact development. New and better guidance may lead to greater recognition of displaced emissions by reporting organizations.
- Many agencies have estimated some part of their impact on GHG emissions, or have had calculations performed by a partner agency. More than one-third of survey respondents have estimated or are estimating emissions generated by their operations. Nearly half of respondents have estimated or are estimating some displaced emissions. Agencies most commonly estimate the mode shift effect of their services. Fewer agencies have estimated the benefits they provide through reduced congestion or compact development.
- More research is needed on methodologies to estimate changes in emissions from specific improvements to transit. Most studies that have analyzed the impact of transit on GHG emissions have focused on existing services. Many of these are limited to analyses at the state or national levels. Very few analyses have covered a full array of strategies that transit agencies can implement to reduce GHG emissions. Even fewer have assessed the cost-effectiveness of such strategies.
- Some transit agencies have initiated formal or semiformal efforts to address GHG emissions. A handful of agencies include GHG emissions in internal sustainability plans or have joined sustainability efforts organized by APTA and the International Association of Public Transport. A few agencies have drafted or plan to draft their own climate action plans. More than two-thirds of agencies have participated in talks or joint efforts with other transportation stakeholders on the topic of climate change.
- A study on best practices, opportunities, and challenges for integrating climate change into transit planning would be helpful. Many transit agencies are struggling with how objectives to reduce GHG emissions will fit with their traditional planning objectives. Several recent studies have examined how metropolitan planning agencies and state departments of transportation integrate climate change into planning objectives and practices. No parallel research has been conducted on transit agencies and transit planning.

Transit agencies can expect federal, state, and local policies on GHG emissions to affect the way they do business in the future. Nearly two-thirds of survey respondents are located in states and cities that have policies related to GHG emissions, including GHG reduction targets, vehicle-miles-traveled reduction targets, and climate action plans. Federal legislation on GHG emissions is expected in the near future. These policies present challenges, as well as funding opportunities, for transit agencies. The uncertainty of future regulations could be addressed in research studies:

- Transit agencies could benefit from focused research and guidance on new funding opportunities related to GHG emissions. A few agencies are actively considering new funding opportunities that might be created by emissions trading schemes or government grant programs. Such opportunities could become an important source of funding.
- Some agencies are unclear about how reporting their emissions might affect their ability to receive credit for current or future reductions. A research study could describe the risks and opportunities that reporting of emissions provides to transit agencies. Such a study might also engage third-party reporting agencies to think more critically about the needs of transit agencies in reporting their emissions.

Many transit agencies see addressing GHG emissions as a challenge. Survey respondents see funding and staffing for GHG planning initiatives as the biggest obstacles. Uncertainty surrounding analysis methodologies, and a general lack of tools and guidance are also concerns. Still, many agencies are taking important first steps to further their role in reducing GHG emissions. Using existing research, agencies can begin to account for the benefits that their services provide to GHG emissions. Transit agencies can also develop new strategies that both reduce GHG emissions and meet other agency priorities.

CHAPTER ONE

INTRODUCTION

SYNTHESIS PURPOSE

As concern about climate change grows in the United States, all sectors of the economy are under pressure to reduce the greenhouse gas (GHG) emissions that contribute to climate change. The transportation sector is a major source of GHG emissions in the United States, accounting for nearly one-quarter of the country's emissions. Policy makers, planners, and transportation agencies are increasingly considering how the transportation sector can reduce its GHG emissions in the short and long terms.

TRB's 1997 *Special Report 251: Toward a Sustainable Future* (*1*), identified transit investments as one of a handful of strategies to reduce and manage GHG emissions from the transportation sector. Subsequent reports from TRB, APTA, and a number of universities, consulting firms, nonprofit organizations, and individuals have continued to find that public transportation reduces GHG emissions from the transportation sector.

The goal of reducing GHG emissions from the transportation sector is a complex challenge with no one single solution. Strategies needed to reduce emissions are based in technology, planning, and policy. Transit agencies can contribute to this goal by increasing ridership, boosting vehicle passenger load factors, and reducing their use of energy from fossil-based sources. This synthesis supplements the existing substantial literature on these topics by explaining the benefits of these and other strategies to reduce GHG emissions.

The purpose of this synthesis report is to equip transit agencies with knowledge of how their services and operations specifically affect transportation GHG emissions. Most transit agencies in the United States are already helping to reduce GHG emissions from transportation just through their normal operations. Some agencies are actively seeking to further reduce GHG emissions. Other agencies are looking for guidance from policy makers and examples from their peers about how best to reduce GHG emissions. This report provides agencies with a summary of the most current research and practices in reducing GHG emissions through public transportation. Transit agencies will benefit from the best information available about the specific ways that transit reduces GHG emissions, techniques to estimate GHG emissions impacts of transit, and practices for planning and policies related to GHG emissions. This synthesis report draws on existing research to provide this knowledge base for transit agencies.

Americans are becoming increasingly aware of the impacts that their transportation habits have on GHG emissions and global climate change. Public transportation is one option that Americans can take to reduce their GHG emissions. Transit agencies should be fully aware of this benefit and be able to capitalize on it to attract more riders and to make the case for more funding.

RESEARCH METHODOLOGY

Research for this synthesis included a literature review, a survey of transit agencies, and follow-up interviews with selected agencies. The literature review covered a full range of research produced on the topic in the last decade. Sources included previous reports from TRB, APTA, and the FTA, as well as reports from universities, nonprofit organizations, and consulting firms. National studies on the public transportation industry, as well as studies and reports from individual states and transit agencies, were included. Ongoing research on the topic was identified through TRB's Research in Progress (RIP) database, as well as through conversations with professionals in the field.

An original survey of transit agencies determined current practices related to reducing GHG emissions. The survey was developed and administered by means of a web-based platform. Candidates for the survey were chosen based on agencies' expressed or likely interest in the topic. A range of agencies of different sizes and geographies were included. Candidates were identified with the help of panel members and APTA. Survey candidates were contacted largely through e-mail. Appendix A provides additional detail on the survey process and a copy of the questionnaire.

Respondents to the survey were transit agency personnel from such departments as environment, corporate and public affairs, planning, operations and maintenance, civil engineering, grants, energy and sustainability, business development, safety, and risk management. Ultimately, 41 agencies responded, resulting in a 66% response rate. Responses were received from agencies in all geographic regions of the United States, with a particularly high number of responses from transit agencies in Florida. Figure 1 maps the location of survey respondents. Agencies are grouped by size, as determined by annual passenger miles traveled (PMT) in 2007. A full list of respondents to the survey is provided in Appendix B.

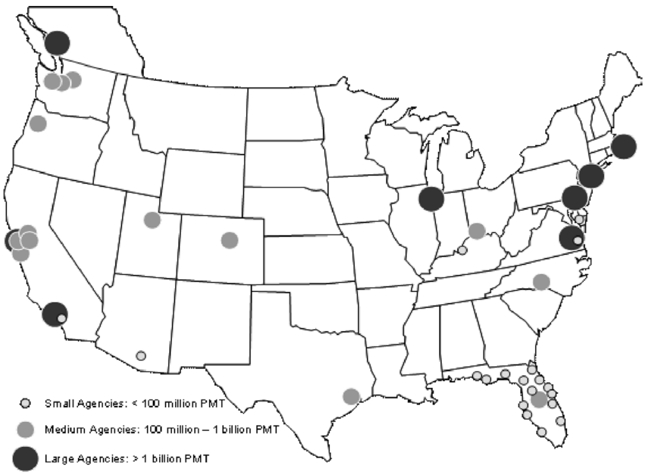

FIGURE 1 Map of survey respondents, by agency size (annual passenger miles traveled) [*Source*: Annual passenger miles traveled (PMT) from National Transit Database (2007)].

The survey included questions about a wide range of topics such as long-range planning, transit facilities, environmental functions, vehicle technologies, construction and maintenance, modeling and analyses, internal and external GHG policies, and staffing. While some respondents consulted other staff within their agencies to arrive at the best answers to individual questions, many surveys were completed by only one individual within the organization. Thus, respondents may have answered questions that are outside their areas of expertise. The reader should keep in mind that individual responses reflect the respondent's best understanding of his or her agency's activities and policies.

Based on information gleaned from the survey and literature review, three transit agencies were selected for follow-up interviews. Agencies were selected for interviews based on their willingness to participate, their depth of experience with reducing GHG emissions, and their implementation of unique strategy types. Interviews with staff of these agencies were conducted over the phone. The results of these interviews are reported as case studies.

REPORT ORGANIZATION

This synthesis report is organized into eight chapters. Following this introduction, chapter two provides a primer on the phenomenon of climate change and transportation's role in climate change. Chapter three describes the basic ways that transit reduces GHG emissions. Chapter four describes in greater detail the specific strategies that transit agencies can implement to reduce GHG emissions. Chapter five explains techniques to estimate the impact of transit and transit strategies on GHG emissions. Chapter six discusses relevant planning and policy issues for transit agencies. Chapter seven presents three case studies of transit agencies that have experience in planning and implementing measures to reduce GHG emissions. Chapter eight provides conclusions and suggestions for further research.

CHAPTER TWO

OUR CHANGING CLIMATE

WHAT IS CLIMATE CHANGE?

Climate models predict that the global climate will shift in a number of ways over the next century. By 2100, we are likely to see global average sea levels higher by 7 to 23 inches. Global average temperatures are expected to rise by between 3.2°F and 7.2°F (*2*). Rainfall patterns are likely to change, with some parts of the world becoming wetter, especially during the winter months, and other parts becoming hotter and drier. The frequency and severity of heat waves and storms may increase. Rising temperatures and higher sea levels, the result of warming oceans and melting ice caps, are already observable in some areas over the last century. During the 20th century, global sea levels rose about 5 to 9 in., and global average temperatures rose by about 1.4°F (*2*).

These phenomena are collectively known as climate change. Most climate scientists now agree that increases in global concentrations of GHGs, largely attributable to humans, are the predominant cause of climate change. Human activities, such as driving cars, producing and consuming energy, and clearing forests, are significant contributors to GHG emissions. The principal source of GHG emissions from human activities is the combustion of fossil-based fuels, including oil, coal, and natural gas.

Climate change may have potentially catastrophic effects on both the natural and human environments as it disrupts ecosystems and threatens buildings, infrastructure, and human health. Expected shifts in climate may reduce crop yields, increase the risk of invasive species, exacerbate drought conditions, and threaten endangered species. The built environment is also at risk. Human settlements in coastal and low-lying areas are particularly vulnerable to changes in sea level and to storm and precipitation events. These areas will almost certainly be at higher risk from flooding as the climate changes. Transportation infrastructure in particular will be threatened by shifts in the global climate. Changes in temperatures, precipitation, and water levels threaten to strain asphalt roadways, railroads, airports, and shipping lanes beyond the design conditions they were built to withstand.

A number of GHGs contribute to global climate change. Of these, carbon dioxide (CO_2) is the most important and the most prevalent in the atmosphere. Other types of GHGs are more potent, though less common, than CO_2. These include methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6).

Climate scientists predict that global GHG emissions will have to be reduced by 50% to 80% below 1990 levels by the year 2050 to avoid the most catastrophic impacts associated with global temperature rise (*3*). An increasing number of nongovernmental organizations and U.S. states are now calling for this scale of reduction in emissions.

GREENHOUSE GAS EMISSIONS FROM PASSENGER TRAVEL

In the United States, transportation is a leading source of the GHG emissions that contribute to climate change. Figures 2 and 3 show the relationship of transportation GHG emissions to other emissions sources. On-road transportation accounts for more than a quarter of the United States' 7,150 million metric tons of CO_2 equivalent ($MMtCO_2e$) annual GHG emissions. Passenger travel in light-duty vehicles [cars, sports utility vehicles (SUVs), and pickup trucks] accounts for nearly two-thirds of U.S. transportation emissions. The remaining transportation emissions come from freight trucks and transportation by air and other modes. Public transportation also produces GHG emissions from buses, trains, and other transit vehicles, but these modes account for less than 1% of total emissions from the U.S. transportation sector, as calculated from 2005 U.S. transit emissions as estimated in Davis and Hale (*4*). [Total U.S. transportation CO_2 emissions in 2005 were 1,882 $MMtCO_2e$, as reported by the EPA (*5*).] Transportation is also the fastest growing source of GHG emissions in the United States. From 1990 to 2006, transportation emissions grew by 25%, although emissions have declined slightly since 2005.

Passenger travel in cars, SUVs, and pickup trucks alone accounts for about 18% of total U.S. GHG emissions. Americans use cars for the majority of trips to work, school, shopping, and entertainment destinations, often driving alone. Public transportation provides a lower-emitting alternative to car-based travel. GHG emissions per passenger mile are often substantially lower for public transportation than for private vehicles.

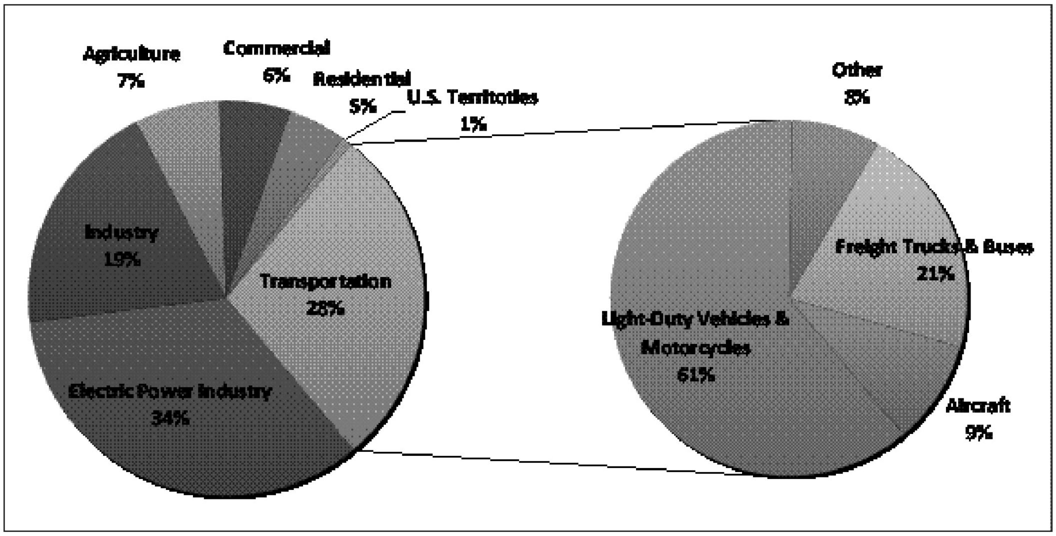

FIGURE 2 U.S. GHG emissions by source, 2007. (*Source*: U.S. Environmental Protection Agency, Inventory of Greenhouse Gas Emissions and Sinks: 1990–2007, Apr. 2009). *Note*: "Other" includes rail, ships and boats, pipelines, and lubricants.

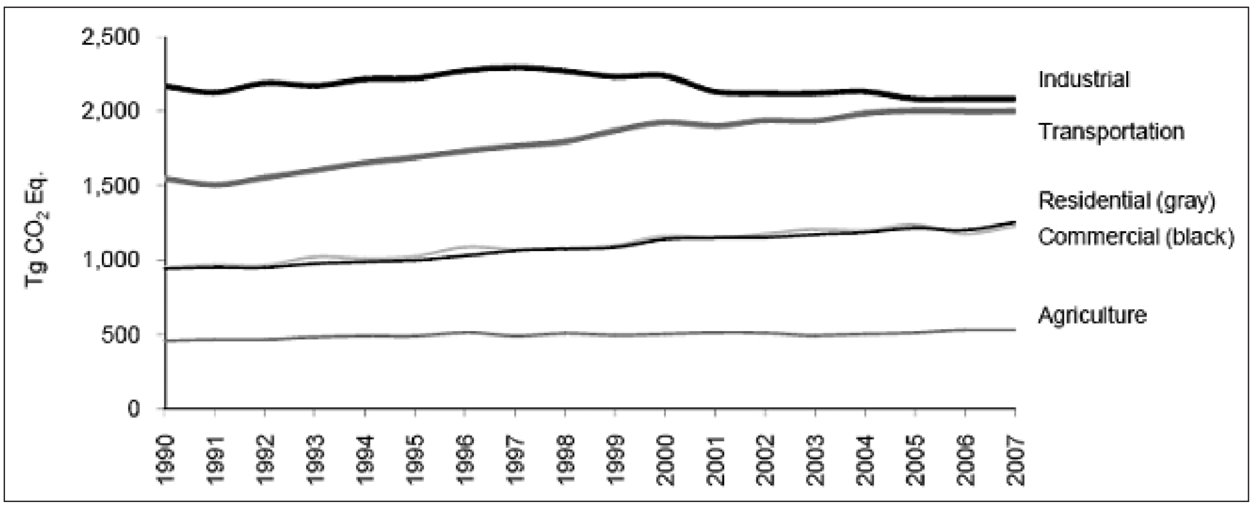

FIGURE 3 U.S. GHG emissions by economic sector, 1990–2007 (with electricity distributed to end-use sectors) (*Source*: U.S. Environmental Protection Agency, Inventory of Greenhouse Gas Emissions and Sinks: 1990–2007, Apr. 2009).

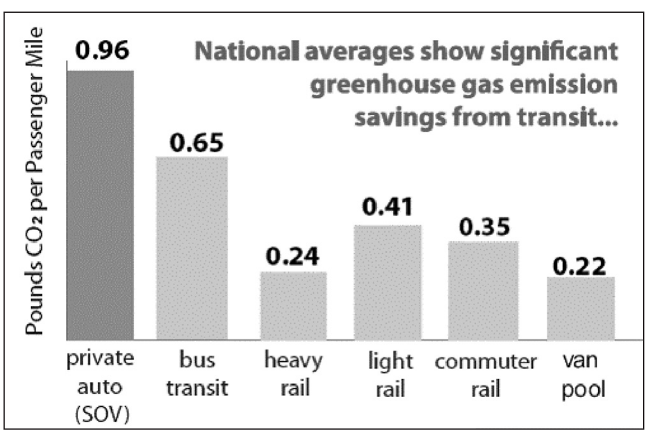

FIGURE 4 National average GHG emissions per passenger mile by mode (*Source*: Hodges, *Public Transportation's Role in Responding to Climate Change*, Federal Transit Administration, U.S. Department of Transportation, Jan. 2009.)

Figure 4 shows average emissions per passenger mile of U.S. transit services versus a single-occupancy vehicle (SOV). Transit emissions from each mode are lower than SOV emissions, because transit vehicles carry multiple passengers at once. The relative GHG efficiency of transit vehicles is based on transit's higher occupancy rates.

CO_2 accounts for the vast majority of GHG emissions from transportation, making up approximately 95% of all GHG emissions from on-road and off-road vehicles. CO_2 emitted from the tailpipes of vehicles is directly proportional to the amount of gasoline or diesel fuel consumed. These petroleum-based fuels contain large amounts of carbon, which, when combusted, combines with oxygen in the atmosphere to form CO_2. Vehicles also emit small amounts of CH_4 and N_2O from their tailpipes. Emissions of these gases depend on the specific fuel and vehicle technologies, and on operating conditions. Vehicles can also emit trace amounts of other GHGs, including HFCs and PFCs from air conditioning and refrigerated units and SF_6 from electrical equipment.

CO_2 emissions are also the most easily estimated of GHGs. Discussion and analyses of GHG emissions from transportation are often limited to CO_2 emissions. When other gases are included in calculations, they can be represented by CO_2-equivalents (CO_2e). CO_2 equivalent measures of other greenhouse gases take into account the potency, or global warming potential (GWP) of each gas. Table 10 in chapter five lists the potency of each gas. Emissions reported in this synthesis are provided in tons of CO_2 or, if other gases are included in the figure, tons of CO_2e. The term “GHG emissions” refers to any or all GHGs.

CHAPTER THREE

ROLE OF TRANSIT IN REDUCING GREENHOUSE GAS EMISSIONS

Transit agencies can both reduce GHG emissions from the transportation sector and reduce their own GHG emissions. Transit reduces, or displaces, emissions from other modes of transportation in three ways. First, buses, vans, trains, and ferries can move more people with less fuel compared with private cars. By shifting passengers from private to public modes, transit saves energy and reduces GHG emissions. Second, transit service can reduce congestion on roadways and thus reduce emissions from vehicles idling in congested conditions. Third, transit service facilitates compact development patterns that allow people to walk and bike instead of drive, thereby saving energy and reducing emissions. In addition to displacing emissions from other modes of transportation, transit agencies also produce some GHG emissions of their own from their use of electricity and vehicle fuels. Furthermore, transit agencies can also reduce and minimize their own GHG emissions by using efficient vehicles and alternative fuels, and decreasing the impact of their auxiliary functions such as construction and maintenance.

Figure 5 diagrams the impacts of transit on GHG emissions, including emissions displaced by and emitted by transit agencies. The following sections explain in more detail the role of transit agencies in reducing their own emissions and displacing GHG emissions through travel mode shift, mitigation of congestion, and compact development.

TRAVEL MODE SHIFT

Shifting trips from private cars to transit vehicles is the most direct way that transit service reduces GHG emissions. Each time someone decides to take an existing bus or train and leave his/her car at home, GHG emissions from that trip are reduced immediately. Most Americans drive alone to work, an average distance of 10 mi each way. The average commuter driving this distance can reduce GHG emissions from her car by 20 lb a day, or 4,800 lb per year, by switching to public transit (*4*). The more people transit agencies can lure out of their cars and onto more efficient trains, buses, and other transit vehicles, the more GHG emissions are reduced.

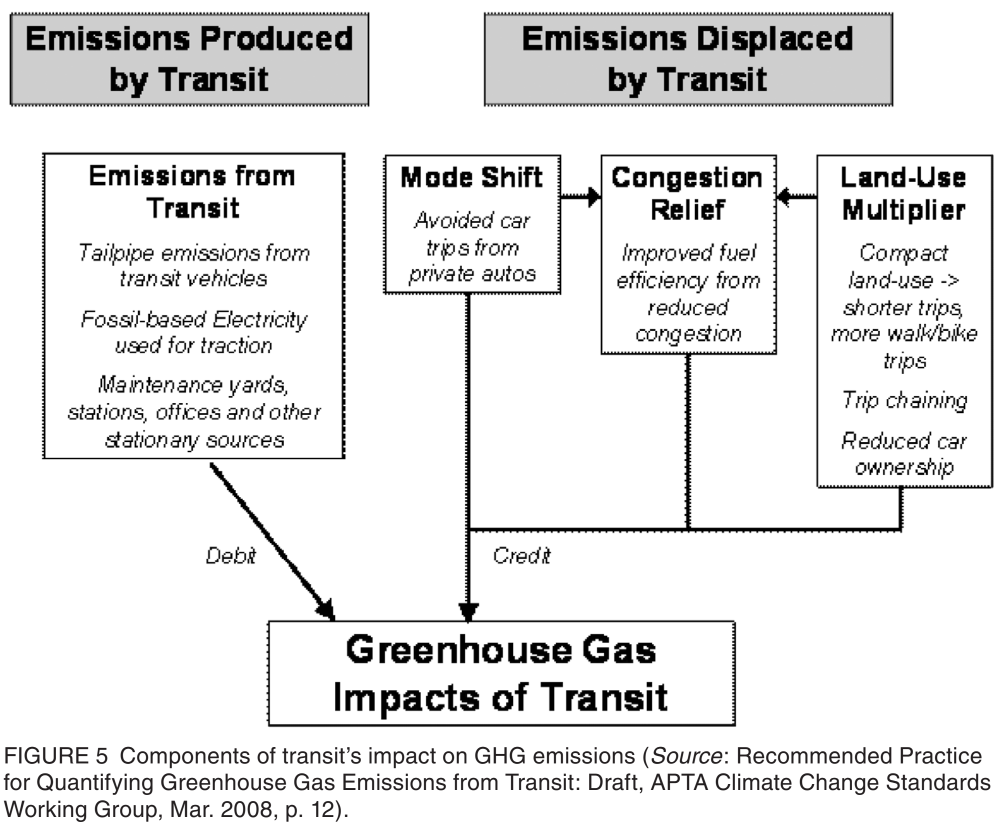

FIGURE 5 Components of transit's impact on GHG emissions (*Source*: Recommended Practice for Quantifying Greenhouse Gas Emissions from Transit: Draft, APTA Climate Change Standards Working Group, Mar. 2008, p. 12).

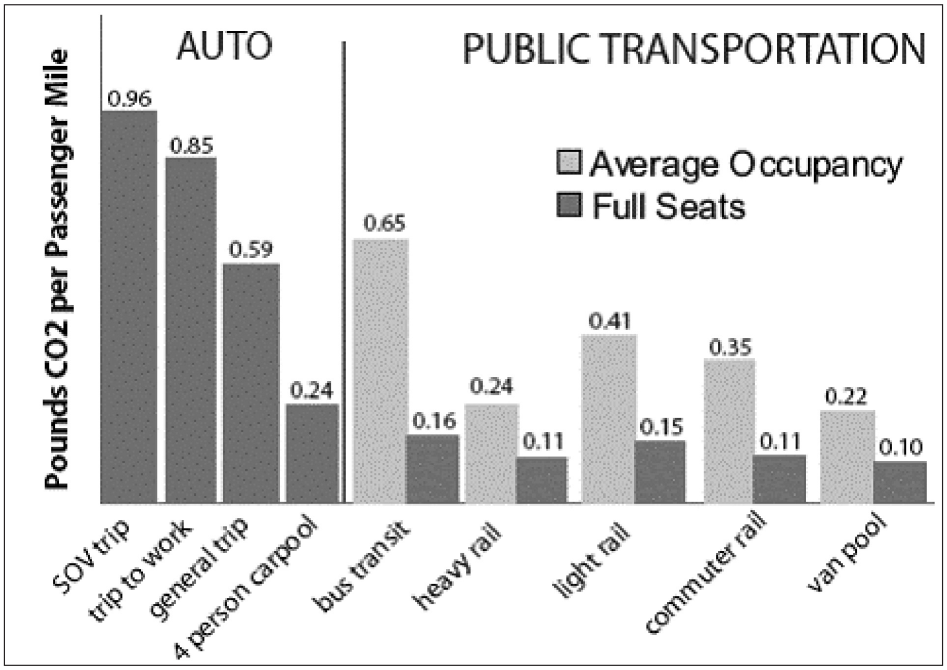

FIGURE 6 Per passenger GHG emissions of transportation options (*Source*: Hodges, *Public Transportation's Role in Responding to Climate Change*, Federal Transit Administration, U.S. Department of Transportation, Jan. 2009). (*Note*: Average vehicle occupancy for commute trips is 1.14. Average occupancy for all trips is 1.63. As reported by the National Household Travel Survey (NHTS) (2001).

Passenger loads on transit vehicles, or load factors, are an important determinant of transit's net impact on GHG emissions. If a transit vehicle is largely empty, its efficiency is eroded. Since most transit vehicles release GHG emissions from their own tailpipes, a bus with only a few passengers can actually emit more GHGs per mile than those passengers would emit traveling in their own cars. Figure 6 shows the effect of vehicle occupancy on the GHG efficiency of various passenger transportation modes. A bus, train, or vanpool with average occupancy is more GHG efficient per passenger mile than an average auto trip to work. On the other hand, a carpool of four people rivals or exceeds the GHG efficiency of an average bus, train, or vanpool, but when transit vehicles fill *all* their seats, they are more efficient than a four-person carpool. A typical 40-seat diesel bus must carry around seven passengers at a time to be more efficient than the alternative of SOVs. The average heavy-rail car must fill 19% of its seats to be more efficient than an automobile carrying an average passenger load of 1.63 (*3*).

Some transit systems in the United States have relatively low load factors; that is, vehicles typically carry few passengers at a time. These systems are inefficient in their GHG emissions. For example, a 2003 study of the Chattanooga Area Regional Transportation Authority (CARTA) found that the transit agency produces a net *increase* in GHG emissions. Low ridership means that emissions from the agencies' buses outweigh savings in GHG emissions from mode shift. GHG emissions in Chattanooga actually would fall if bus service were discontinued and riders switched to driving instead. The study also noted that reducing GHG emissions are not the only benefit, or even the main benefit, that transit systems provide (*6*). For example, CARTA provides travel choices for those who cannot or choose not to drive, including people of low income, children, and seniors. CARTA should not be viewed as a failure just because it increases net GHG emissions. CARTA may have opportunities to reduce GHG emissions by increasing ridership on its existing service or by restructuring its service to focus on more heavily used routes, but the agency must consider impacts on the local community in addition to impacts on GHG emissions.

U.S. transit agencies can directly reduce GHG emissions by increasing ridership on their existing services, so that more people leave their cars at home on a daily basis. Currently, the United States falls far short of other industrial countries in transit ridership. A 2002 study found that the net impact of the travel mode shift induced by U.S. transit, weighed against emissions from transit, is a savings of 7.4 million metric tons of carbon dioxide ($MMtCO_2$) per year, or about as much emitted by the transportation sector in the state of New Hampshire. If Americans increased their transit mode share to the level of Canadians, that reduction would increase to 50 $MMtCO_2$, about the amount emitted by transportation in Louisiana annually. If U.S. transit mode share increased to the level of Europeans, the annual reduction would be 74 $MMtCO_2$, as much as all transportation in Pennsylvania emits each year (*7,8*). Although historical development patterns have facilitated higher transit mode share in Canada and Europe than in the United States, the comparison demonstrates the scale of transit ridership achievable in industrial countries.

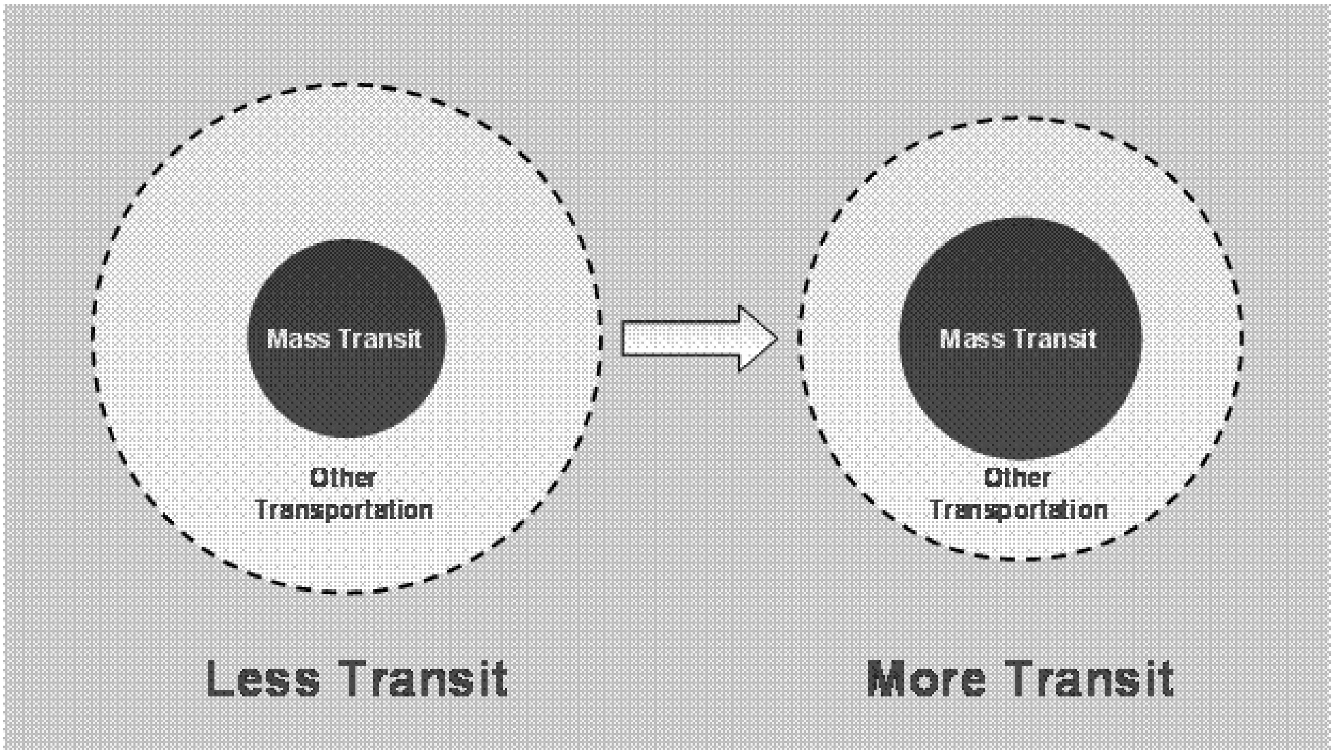

FIGURE 7 Transit share of regional transportation emissions (*Source*: "Greening Mass Transit & Metro Regions: A Synopsis of the Final Report of the Blue Ribbon Commission on Sustainability and the MTA," Metropolitan Transportation Authority, State of New York, Feb. 2009, p. 20).

At the regional level, an expansion of well-used transit service will tend to increase GHG emissions from transit as more miles are traveled by transit vehicles, but total transportation GHG emissions will shrink as new transit riders leave their cars at home. Figure 7 illustrates this relationship. When transit service is well used, more transit service increases transit emissions, but decreases emissions from the rest of the transportation sector. The net effect is to lower total transportation GHG emissions.

CONGESTION MITIGATION

Roadway congestion is an additional source of GHG emissions from transportation. Vehicles burn fuel not just when they are traveling, but also when they are idling in traffic. Driving at slower than optimal speeds also burns extra fuel and therefore emits extra GHG emissions. The Texas Transportation Institute's (TTI's) *Urban Mobility Report* estimates that congestion consumes an extra 120 million gallons of gasoline annually on average in each of the nation's 14 largest urban areas (*9*). That figure translates roughly to 1 $MMtCO_2$ per urban area.

Transit reduces congestion on roadways by taking private vehicles off the road. A full bus or light-rail car takes up less space on the road than each passenger would if he or she drove their own car. Commuter rail systems and subway systems free up even more space on the road. The scale of the benefit per vehicle depends on the passenger load. The Urban Mobility Report finds that transit reduces congestion-related delays an average of 31 million hours in each of the country's 14 largest urban areas. In 2005, public transportation reduced congestion-related combustion of gasoline by 340 million gallons. A Science Applications International Corporation (SAIC) study estimated that saving that amount of gasoline is equivalent to reducing GHG emissions by 3 $MMtCO_2$, or twice the amount emitted annually by transportation in Washington, DC (*4,8*).

COMPACT DEVELOPMENT

Transit systems are associated with compact development patterns. An extensive body of research finds that areas with higher population and employment density typically have better public transportation systems than areas with lower population and employment density (*10*). Transit systems tend to be more robust and more highly used in compact urban areas. Transit stops in compact areas provide access to more destinations, including workplaces and shops, and are therefore more convenient to use than stops in other areas. In compact areas, more people can also live within easy access of transit stops, allowing transit systems to attract a higher ridership.

High-quality public transit also has the ability to influence urban development. High-quality transit reduces the need for more road lanes and large parking lots. Higher land prices around transit stations promote more compact development as residents and businesses economize on space. In addition to market forces, good urban planning also dictates that development should be focused around transit nodes to maximize the use of transit. Thus, transit and compact development tend to beget one another in a virtuous feedback loop.

By encouraging compact development, transit indirectly affects even the travel patterns of people who do not take transit. Compact communities typically allow people to travel shorter distances to get from place to place, as homes and businesses are closer together. Those who do drive can drive fewer miles. Compact communities also tend to be friendly places for walking and biking, which eliminate vehicle trips altogether; and areas rich in transit tend to have lower rates of car ownership than other areas. These impacts of transit on the travel patterns of nontransit riders have been demonstrated in various urban contexts. A 2000 paper by Holtzclaw reviewed six previous studies that compared travel patterns in major urban areas in the United States and abroad. The studies showed that impacts of transit systems on travel patterns were greater than miles traveled on transit alone by a factor of 1.4 to 9. Older transit systems tended to have greater impacts than newer transit systems (*11*). The sum of such impacts on travel patterns is substantially less driving in compact communities.

Transit-oriented development (TOD) is a type of compact development explicitly associated with transit. TOD is usually characterized by above-average densities, orientation to pedestrian activity, and easy walking access to a major public transit station or stop. The objectives of TOD can include the following:

- Increasing opportunities for travel by transit,
- Attracting new riders to transit,
- Shifting transit access trips from driving to walking,
- Reducing automobile activity associated with new developments, and
- Reducing energy use and associated emissions from transportation.

TODs can exist in urban or suburban areas; mix office, retail, and residential space; and provide access to rail or high-quality bus service (*12*).

A significant body of research is devoted to the impact that TODs have on the travel habits of residents. Most studies find that residents of TODs use transit more and drive less than their counterparts in other types of developments. Residents of TODs typically drive fewer miles to work than before moving to the area (*13*). *TCRP Report 128* examined TODs in four metropolitan areas and found that TOD housing produced considerably less traffic than conventional development. TODs surveyed averaged 44% fewer vehicle trips on a weekday than predicted by the ITE Trip Generation manual, the standard resource for estimation of vehicle trips in conventional developments (*8*). Many more studies have examined the impacts of TOD on residents' travel behavior, the potential for TOD to shift travel patterns at a regional or national scale, and design characteristics of TOD. *TCRP Report 128* contains an extensive literature review and bibliography.

EMISSIONS FROM AGENCY OPERATIONS

In addition to displacing emissions from private vehicles, transit produces its own GHG emissions. These emissions come from the tailpipes of transit vehicles and nonrevenue vehicles owned by the agency, from office buildings and maintenance yards, from transit stations and other facilities, from construction of transit systems, and from the travel patterns of transit agencies' employees. The following subsections discuss these sources of emissions in greater detail. Strategies to reduce emissions from agency operations are discussed in chapter four.

Transit Vehicles and Fuels

Tailpipe emissions from transit vehicles are the primary source of GHG emissions from transit. All transit vehicles are responsible for some GHG emissions. Vehicles powered by conventional fuels and most alternative fuels emit GHGs from their tailpipes. Vehicles powered by electricity are responsible for some GHGs emitted from electric plants. In 2006, U.S. transit vehicles used 735 million gallons of diesel fuel (see Table 1). Combusting that amount of diesel produces roughly 7.4 $MMtCO_2$, or about as much emitted by transportation in the state of New Hampshire each year (*8*).

TABLE 1
DIESEL FUEL USE BY PUBLIC TRANSPORTATION, 2006

Mode	Million Gallons
Bus	536.7
Commuter Rail	78.6
Paratransit	86.8
Ferry Boat	33.5
Other	0.2
Total	**735.1**

(*Source:* Neff, *2008 Public Transportation Fact Book, Part 2: Historical Tables,* APTA, Washington, D.C., June 2008).

In addition to the emissions from energy used to propel transit vehicles, the vehicles themselves are also sources of GHG emissions "upstream" from the point of use. The manufacture of transit vehicles requires raw materials including glass, rubber, plastics, steel, and other metals. Energy is needed to extract, process, and assemble these materials. Emissions associated with these steps are known as embodied emissions. Materials and energy are also required to maintain vehicles throughout their lifetimes, as they require tune-ups and new parts. At the end of a transit vehicle's useful life, energy is required to disassemble and scrap the vehicle. Each of these processes within the life cycle of the vehicle uses carbon-based energy and is therefore responsible for GHG emissions.

A research team at the University of California, Berkeley, conducted an extensive analysis of GHG emissions from each life-cycle component of auto, bus, light-rail, and heavy-rail transportation. Figure 8 shows the relative life-cycle impacts of cars, SUVs, pickups, and buses, as calculated in that study. A typical bus running during peak hours, with 40 passengers, has the lowest emissions per passenger mile traveled. A typical bus running during off-peak hours, with only five passengers, has the highest emissions of GHGs per passenger mile traveled. The study assumed average passenger loads of 1.58 for sedans, 1.74 for SUVs, and 1.46 for pickups.

Although tailpipe emissions account for the majority of life-cycle emissions for each mode examined, nontailpipe emissions from vehicles can be substantial. An average transit bus emits 1,240 metric tons of CO_2 equivalent ($MtCO_2e$) from the tailpipe in its 12-year lifetime. The manufacture, repair, and maintenance of the bus over its lifetime produce another 183 $MtCO_2e$, or an additional 15%. An average sedan emits 69 $MtCO_2e$ from the tailpipe in its lifetime. The manufacture, repair, and maintenance of the sedan produce another 13 $MtCO_2e$, or an additional 19% (*14*).

Facilities, Stations, and Maintenance Yards

Transit agencies use energy not only in transit vehicles, but also in all buildings and structures that they maintain. Every transit agency requires office facilities, which consume energy for heating, cooling, lighting, and computers and electrical equipment. Office facilities also consume materials (particularly paper) that require energy to produce, transport, and discard. Larger transit agencies and agencies with rail transit also maintain transit stations that require heating, cooling, lighting, and energy for electrical equipment. Finally, transit agencies require maintenance yards to keep up their fleets of buses and trains. Any energy used in these maintenance yards that is derived from carbon-based fuels results in GHG emissions.

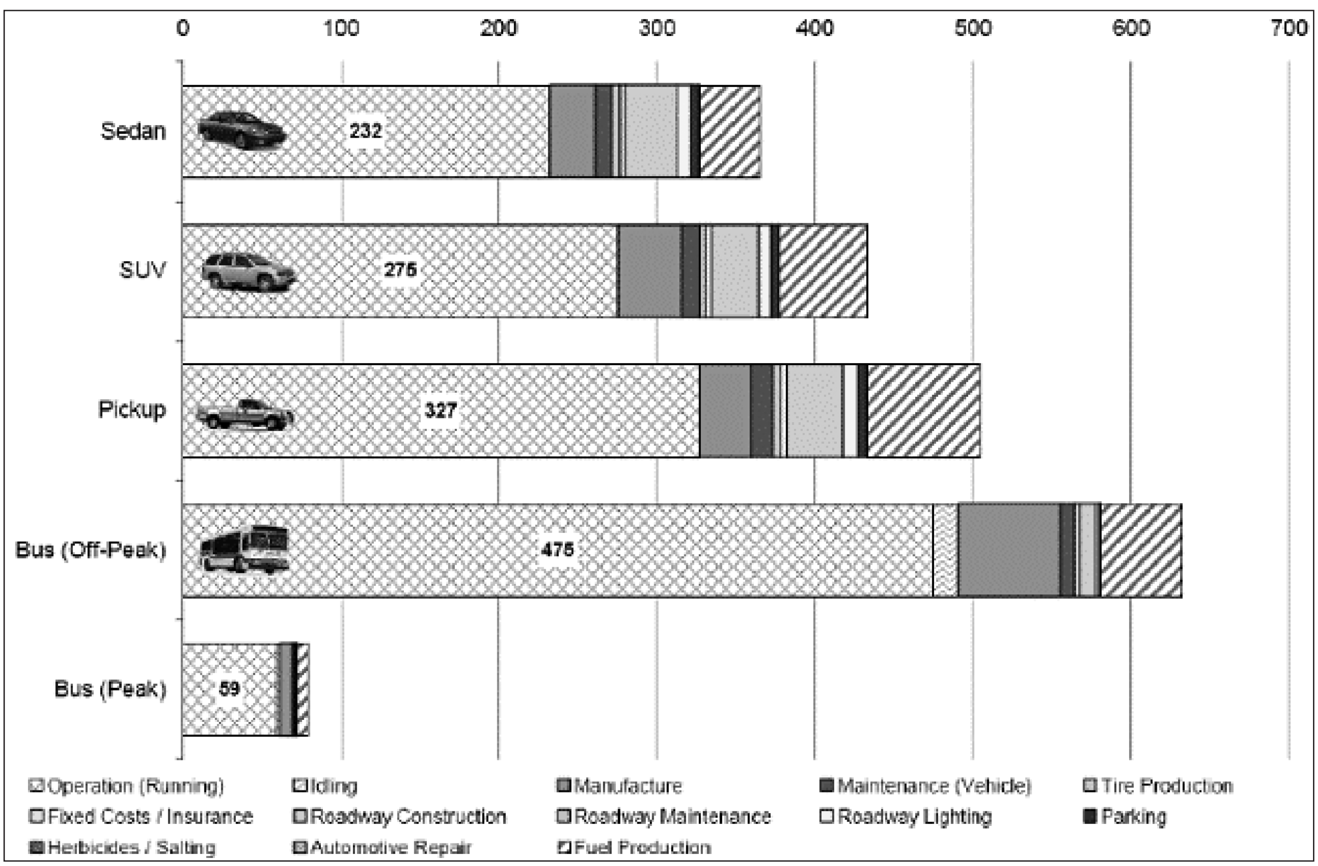

FIGURE 8 Vehicle and infrastructure life-cycle emissions by mode (grams of CO_2e per passenger mile traveled) (*Source*: Chester, *Life-cycle Environmental Inventory of Passenger Transportation in the United States*, Institute of Transportation Studies, Dissertations, University of California, Berkeley, 2008.)

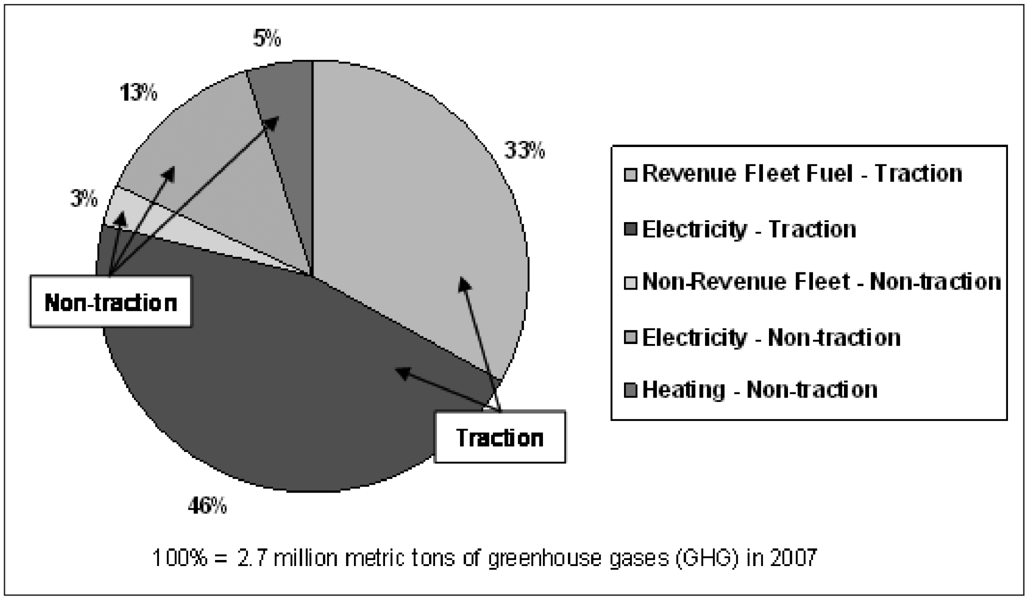

FIGURE 9 New York MTA GHG emissions by source, 2007 (draft) (*Source*: *Greening Mass Transit & Metro Regions: A Synopsis of the Final Report of the Blue Ribbon Commission on Sustainability and the MTA*, Metropolitan Transportation Authority, State of New York, Feb. 2009, p. 22).

While transit vehicles account for the majority of energy used by a typical transit agency, buildings are also important consumers of energy. Of the 2.7 MMtCO_2e emitted by the New York Metropolitan Transportation Authority (NYMTA) in 2007, 18% are attributed to electricity and heating in the agency's facilities, stations, and maintenance yards. Figure 9 illustrates the sources of the agency's emissions. Traction energy, or energy used to propel transit vehicles, accounts for 79% of emissions. All other energy is considered nontraction. NYMTA's inventory does not include embodied emissions related to the agency's vehicles and infrastructure.

Construction and Maintenance

Depending on the modes used, transit systems may require significant construction efforts. Rail systems are the most construction intensive, often requiring that miles of new track and new stations be constructed as systems are initiated or expanded. Transit agencies also construct and maintain bus stations, bus shelters, and park-and-ride lots. Construction and maintenance of all transit offices, facilities, and infrastructure use energy and produce GHG emissions:

- From on-road transportation of materials, construction workers, and waste;
- From construction equipment; and
- Emissions embodied in any materials used.

Other Emissions

Transit agencies also maintain nonrevenue vehicle fleets used for maintenance and local travel. These vehicles emit GHGs as well. At NYMTA, 3% of GHG emissions are attributed to nonrevenue vehicles (see Figure 9). Many employees of transit agencies emit GHG emissions from their own vehicles as they commute to and from their jobs, although these emissions may or may not be attributed to the agencies themselves.

NET IMPACT OF U.S. TRANSIT ON GREENHOUSE GAS EMISSIONS

Four recent studies have estimated the net amount of GHG emissions that U.S. transit services save each year. All have found that American public transit significantly reduces GHG emissions from the transportation sector. Each of the studies accounted for the travel mode shift effect of transit and for transit vehicles' emissions. Some of the studies also accounted for the compact development and congestion mitigation effects of transit. Reductions range between 6.9 MMtCO_2 and 36.6 MMtCO_2, depending on the scope of displaced emissions considered. For comparison, emissions from all on-road transportation in the state of Washington in 2005 totaled 32.3 MMtCO_2e (*15*).

Table 2 provides the results of individual studies. Estimates of mode shift and congestion reduction impact are similar across the studies. Of the two studies that estimated the impact of compact development, the study by ICF International calculates the greatest reduction. The statistical technique used by ICF to capture land use effects of transit is more comprehensive than that used in the California's Public Interest Research Group (CALPIRG) study (see chapter five, Compact Development for more information). The results of the CALPIRG study are buoyed by two other factors:

TABLE 2
AGGREGATE GHG REDUCTIONS FROM PUBLIC TRANSIT IN THE UNITED STATES

Study Author	Study Date	Emissions Impact ($MMtCO_2$)				
		Mode Shift	Congestion Reduction	Compact Development	Transit Emissions	Net
ICF Intl.	2008	-15.8	-3.0	-29.9	12.1	-36.6
CALPIRG	2008	—	—	—	—	-25.8
Shapiro et al.	2002	-16.5	N/A	N/A	9.1	-7.4
SAIC	2007	-16.2	-3.0	N/A	12.3	-6.9

Sources: Bailey et al., *The Broader Connection between Public Transportation, Energy Conservation and Greenhouse Gas Reduction*, ICF International, 2008 (*10*); Davis and Hale, *Public Transportation's Contribution to U.S. Greenhouse Gas Reduction*, Science Applications International Corporation, 2007 (*4*); Baxandall et al., *A Better Way to Go: Meeting America's 21st Century Transportation Challenges with Modern Public Transit*, California's Public Interest Research Group Education Fund, 2008 (*16*); Shapiro et al., *Conserving Energy and Preserving the Environment: The Role of Public Transportation*, 2002 (*7*).

Note: Figures from the ICF study are calculated from figures in Tables 2 and 3 in that report using a conversion of 1 billion gallons of gasoline = 8.8 $MMtCO_2$. A dash (—) indicates that separate figures were not provided. N/A indicates that the effect was not included in the calculation.

1. CALPIRG did not include demand response services, which tend to be inefficient in GHG emissions, in its estimate. The authors reasoned that including demand response in the estimate would mask the benefit of fixed-route services.

2. CALPIRG estimated lower emissions from electric transit vehicles in some regions, because it accounted for regional variations in sources of electricity. The other studies assumed an average national mix of electricity generation.

Results also vary between the studies depending on the year of data used and modes included. For example, the Shapiro study (*7*) used older data than the other studies, and included only bus and rail modes.

Individual transit agencies have different net impacts on GHG emissions, depending on their sizes, types of service, fleets, sources of energy, and operating parameters. Based on analysis of a sample of 503 U.S. transit systems, the CALPIRG study concluded the following:

- Rail transit systems reduce emissions the most, in large part because of the land use impacts of rail in dense urban settings, and because of the use of electricity as a transportation fuel.
- Bus systems have smaller, but still important impacts to reduce GHG emissions.
- Vanpool programs provide relatively high savings on a per passenger basis.
- Even most small transit agencies also provide GHG savings (*16*).

From a sample of 50 of the largest transit agencies, the study found that agencies' impacts ranged from a net reduction of 10.5 $MMtCO_2$ per year to a net increase of 0.07 $MMtCO_2$ per year. Only one agency produced a net increase in GHG emissions. Appendix C provides estimates from CALPIRG of the impact of individual transit agencies on GHG emissions.

CHAPTER FOUR

TRANSIT STRATEGIES TO REDUCE GREENHOUSE GAS EMISSIONS

Transit agencies can reduce GHG emissions from transportation by reducing the amount of miles traveled in private vehicles, by reducing congestion, by catalyzing compact development patterns, and by reducing their own emissions. Agencies can pursue specific strategies to achieve reductions in each of these areas. Some strategies reduce GHG emissions through more than one of the four mechanisms. Ultimately, any strategy that reduces the consumption of fossil-based energy will reduce GHG emissions. This chapter provides an overview of the various types of strategies, results from the survey, and specific examples of strategies from some transit agencies.

Results from the survey of transit agencies in Table 3 demonstrate the prevalence of different strategy types. Strategies that increase vehicle passenger loads are the most common among survey respondents, followed by strategies that improve transit vehicle fuel economy through operations and maintenance techniques. Use of alternative fuels was cited least frequently, but all strategy types were cited by at least two-thirds of survey respondents. Note that some individual strategies may fall into more than one of the categories in Table 3.

TABLE 3
AGENCIES PURSUING STRATEGIES THAT REDUCE GHG EMISSIONS (% of 41 respondents)

Strategy Categories	Planning or Implementing
Increasing Vehicle Passenger Loads	93%
Vehicle Operations and Maintenance	90%
Mitigating Congestion	88%
Alternative Fuel and Vehicle Types	90%
Other Energy Efficiency/Renewable Energy Initiatives	83%
Expanding Transit Service	78%
Construction and Maintenance	73%
Promoting Compact Development	70%

Many strategies that reduce GHG emissions are already common across agencies because they address agencies' traditional goals. A number of the strategies work by increasing ridership or reducing energy consumption. Transit agencies typically pursue these strategies primarily to broaden their customer base, improve customer service, and reduce costs. Some strategies also reduce emissions of criteria pollutants, as required by existing environmental regulations, or reduce congestion, in keeping with federal transportation planning statutes. Reducing GHG emissions is often seen as a co-benefit, rather than a goal, of strategies. For each category of strategies, survey respondents indicated how GHG emissions factored into decision making. Respondents chose one of four options:

1. Reducing GHG emissions is a principal factor in the agency's decision to pursue these strategies.
2. Reducing GHG emissions is a factor in the agency's decision to pursue these strategies, but not a principal one.
3. The agency is aware of the potential impact of these strategies on GHG emissions.
4. The agency has not considered the impact of these strategies on GHG emissions.

Results are reported in each subsection.

A principal way that transit agencies can reduce GHG emissions is to increase transit ridership so that fewer people drive their cars to reach their destinations. Existing transit agencies can increase ridership in two primary ways: offering more transit service, and enticing people to make better use of transit service. Agencies often pursue the two strategy types in tandem, to ensure that new services are well used.

Some factors that affect transit ridership are beyond the immediate control of transit agencies. For example, existing urban forms, the price of fuel, and the price of parking all influence transit ridership. Although fuel prices fluctuate in response to broad economic trends, local agencies do control urban development patterns and the price of publicly owned parking. Local agencies can use such levers to support the use of transit. The most successful transit systems are not a product of one transit agency working alone, but of a partnership of transit and other public agencies supporting transit through good urban planning and policy. Nevertheless, transit agencies can take some steps on their own, and can initiate some strategies with the help of partners, to increase ridership and reduce GHG emissions.

EXPANDING TRANSIT SERVICE

Expanding transit service, or increasing the supply of public transportation, allows more people to use transit for a greater number of miles traveled. Agencies can expand transit service by increasing the geographic coverage of routes, increasing service frequencies, extending operating hours, and adding new transportation modes. Adding route miles might include establishing new modes of public transportation within a given area, such as light rail transit (LRT) or bus rapid transit (BRT), that provide higher quality service than the traditional bus services that account for the majority of transit in the United States.

To reduce GHG emissions, expanded transit service must achieve some minimum vehicle occupancy rate. The net impact of each individual strategy on an agency's GHG emissions depends on the balance of new ridership and tailpipe emissions from additional transit vehicles. Agencies should consider both factors in planning any expansion strategies to reduce GHG emissions.

Expanding Route Coverage

Expanding the coverage of transit routes both increases the number of people who can access transit and reduces average times to access transit. The proximity of transit service is a major factor determining Americans' use of public transit. Statistical analyses show, for example, that the density of rail service in a given area is positively correlated with the distance traveled by public transportation (*17*). The distance from a person's home to the nearest transit stop is particularly influential. A number of studies have found that people's willingness to walk to a bus stop drops off dramatically at distances greater than one-quarter mile. People may travel several miles by bicycle to access transit (*18*). Expanding the number of households within these transit-accessible boundaries encourages more households to use transit.

The EPA COMMUTER model estimates changes in transit mode share based on variables including the proximity of transit. The model draws on empirical studies in a number of U.S. urban areas. Depending on the specific urban area, the model predicts that the mode share of transit will increase by between 0.02% and 0.09% for every 1 min decrease in average walk time to transit (*19*).

A TCRP report examined the impact of expanded coverage of bus service on ridership. Specific types of expansion include the following:

- New Bus Transit Systems
- Comprehensive Service Expansion
- New Coverage in Urban Areas
- New Suburban Connections
- New Circulator/Distributor Routes
- New Feeder Routes
- New Routes Connecting Disadvantaged Neighborhoods to Jobs

Based on a sample of empirical studies, the report found that ridership on most systems will increase by between 0.6% and 1% for every 1% increase in bus miles or bus hours operated. Some studies show response rates well outside of this band. These figures suggest that passenger load factors fall on average as service increases, but results will vary from agency to agency and depend on the time scale of analysis. In general, ridership increases tend to be greater on systems with below-average service levels (*20*).

A 2007 study by ICF International found that approximately 51% of American households in 2001 had access to transit within 0.75 mi of their home. A household within this band tends to drive 11.3 mi less each day than an identical household outside the band. That study found that, between 1999 and 2004, two-thirds of the ridership increase on U.S. transit services came from new route miles. The remaining one-third came from increased ridership on existing route miles. If transit agencies added 11,700 bidirectional route miles of rail transit and bus transit, the proportion of households within 0.75 mi of transit would increase to 64%, and public transit ridership would approximately double. As of 2007, about 3,858 route miles of rail service were at the stage of engineering, construction, planning, or proposal. The equivalent amount of high-quality bus route miles was unknown (*21*).

Increasing Service Frequency

Increased frequency of service can attract more riders to existing transit route miles. More frequent service reduces the average time that passengers spend waiting at stations and bus stops, thereby reducing the total time needed for travel, reducing the time that passengers may have to spend in inclement weather conditions, and reducing the need to plan around infrequent service schedules.

Frequency of public transportation has a measurable impact on ridership. A 2004 study found that the share of trips made by automobile decreases significantly as service frequency at the nearest bus stop increases (*22*). A separate TCRP study found that for a 1% increase in bus service frequency (or decrease in headway), ridership increases between 0.3% and 1%, with an average of 0.5%. For a 1% increase in train service frequency (or decrease in headway), ridership increases between 0.08% and 0.9%. These figures indicate that passenger load factors are likely to fall as frequency increases, but results for individual agencies vary based on current service levels (*23*). The COMMUTER model estimates that a 1 min decrease in average transit wait time will increase transit mode share by between 0.02% and 0.1% (*19*).

An analysis by ICF International used the Transportation Demand Model Evaluation Model to predict the impact of increased transit service frequency on transit ridership and corresponding GHG emission reductions. The analysis was based on a proposed increase in funding for U.S. agencies. ICF estimated that the funding increase would reduce average waiting times for transit vehicles by 1.6 min in most metropolitan areas, and by 0.3 min in large metro areas with robust transit service, by 2020. The additional ridership expected from reduced wait times would reduce 600,000 metric tons of GHG emissions in 2020, not accounting for any increase in emissions from transit vehicles (*24*).

Extending Operating Hours

Agencies can also extend their hours of operation to attract more riders. Most transit agencies provide the highest level of service during peak and midday hours, with less service in the early morning and late evening hours. Restricted operating hours typically force people who must make trips in the early morning and late at night to drive. Expanded hours provide an opportunity for those people to take transit instead. Extending operating hours can also include adding weekend service.

Some transit agencies have measured systemwide ridership increases in response to extended operating hours. The Whatcom Transportation Authority in Washington State increased ridership substantially by adding a single new evening route. In Dallas, new weekend service on suburban shuttles prompted a measurable increase in *weekday* ridership (*23*).

Of the 41 transit agencies who responded to the survey, about three-quarters are currently increasing or planning to increase their service offering. Table 4 summarizes agencies' responses. The most common ways that agencies are increasing transit service are by increasing the geographic coverage of service and by adding new types of transit service, such as BRT or LRT. More agencies are at the stage of planning transit expansions rather than implementing expansions. For example, the Denver Regional Transportation District (RTD) is planning a new commuter rail service. Agencies noted that their budget problems are a particular concern for expansion plans. King County Metro is reconsidering plans to expand service in light of budgetary shortfalls. The Washington Metropolitan Area Transit Authority (WMATA) and the San Francisco Bay Area Rapid Transit District (BART) are among agencies considering cutting service. Portland's Tri-County Metropolitan Transportation District of Oregon (TriMet) is cutting some services even as it expands light-rail service.

TABLE 4
AGENCIES PURSUING SERVICE EXPANSION STRATEGIES
(% of 41 respondents)

Strategy Types	Planning	Implementing	Planning or Implementing
Expanded route coverage	61%	32%	68%
Increased service frequency	46%	27%	51%
Increased hours of operation	24%	10%	27%
New service types (e.g., BRT or LRT)	61%	20%	68%
Other strategies	17%	0%	17%
Any strategy			78% (32 agencies)

Although strategies to expand service can increase the GHG savings that transit agencies provide, individual agencies consider those savings to different degrees. Agencies were asked to characterize the role that GHG emissions played in the decision to pursue these strategies. Almost all agencies expanding or planning to expand transit service are aware that these strategies can reduce transportation GHG emissions. Nearly half said that reducing GHG emissions was a factor in the decision to expand service. Five agencies, Montgomery County Department of Transportation (DOT), TransLink, Sound Transit, Los Angeles County Metropolitan Transportation Authority (LACMTA), and Lee County Transit, reported that GHG emissions were a principal factor in their decisions to expand service. These responses indicate that most expansions of transit service are not driven by the benefits of reduced GHG emissions; but many transit agencies do consider GHG emissions as a co-benefit.

INCREASING VEHICLE PASSENGER LOADS

In addition to increasing the supply of public transportation, transit agencies can also implement strategies to increase the number of riders on transit vehicles. Vehicle passenger loads are a crucial factor in determining the net impact of transit on GHG emissions. Transporting more riders per vehicle is a particularly effective way to reduce transportation GHG emissions, because it does not require operating additional buses or trains, which themselves emit GHGs. Increasing ridership on existing vehicles also tends to be a more cost-effective way to reduce GHG emissions than increasing the supply of public transit. New vehicles and supporting infrastructure are costly for transit agencies.

To attract riders, it is important that transit not merely be an option for travel, but that it be an attractive option that competes, in particular, with the private auto. Transit agencies can boost ridership on their vehicles by improving access to transit, improving the comfort and safety of transit, improving the speed and reliability of service, and providing information about and incentives to use transit. Agencies may also be able to increase ridership, without expanding total service, by optimizing their service routes. Some individual strategies may fall into more than one of these categories.

Improving Transit Access, Comfort, and Safety

Various strategies can boost transit ridership by improving riders' experiences traveling to and from transit stops. Improvements to bicycle and pedestrian pathways to stops and stations, with the collaboration of local governments, make transit a viable and attractive travel option for more people. Pedestrian and bicycle connections to transit can both attract new riders and encourage people who previously drove to transit stops to walk or bike instead. Parking and drop-off and pick-up facilities at transit stations can also attract more riders, but strategies that encourage nonmotorized connections to transit generally have a higher potential to reduce overall GHG emissions. One agency surveyed, Sacramento Regional Transit District, is working with its city and county on a "Complete Streets" policy. Complete Streets include robust facilities for pedestrians and bicyclists, in addition to transit vehicles and private vehicles.

Improvements to transit vehicles also improve access to transit for some people. Bike racks at transit stops and on buses improve access for bicyclists. Providing wheelchair ramps and lifts and low-floor buses improves accessibility for elderly and disabled patrons.

Changes to transit stations and stops can improve passengers' experiences while waiting for buses and trains. Passengers spend between 10% and 30% of a typical transit trip waiting for vehicles. This time can be made more pleasant by providing comfortable and clean waiting areas that protect passengers from the weather, minimize exposure to traffic, provide transit information and amenities, and address security concerns by providing visibility and emergency response (*24*). For example, the Congestion Mitigation Air Quality (CMAQ) program provided funding for improved bus waiting areas in Kansas City, Missouri, with the intent of increasing bus ridership. The project constructed shelters at 100 bus stops that featured a coordinated look and feel and provided route and schedule information (*25*).

A guidebook from the Florida DOT provides design guidelines for high-quality public transit stations and shelters as well as improving access for pedestrians, bicyclists, the disabled, and elderly. The resource provides specific parameters for coordination of elements at bus stops including signs, benches, shelters, lighting, landscaping, and amenities. At the street level, the guidebook provides parameters on connecting bus stations and stops to pedestrian and bicycle circulation. The guidebook also includes ways to increase passengers' perceptions of safety at bus stops (*26*). Use of such guidelines can form part of an overall GHG reduction strategy for transit agencies.

Improving Service Speed, Reliability, and Convenience

Improvements to service speed and reliability can make transit as attractive as or more attractive than travel by private automobile. Longer trip times and less reliable trip times on transit are a major deterrent for many would-be transit users. To the extent that agencies can reduce travel times and improve reliability, they may attract more riders. Waiting times for transit vehicles and in-vehicle trip times have measurable impacts on ridership. The COMMUTER model predicts that for each minute average wait times at transit stops are reduced, transit mode share will increase by 0.02% to 0.1%. For each minute that average in-vehicle trip times are reduced, transit mode share increases by 0.01% to 0.05% (*19*).

Strategies to reduce time spent waiting for transit and traveling on transit include express bus services, timed transfers, consolidating bus stops, regularized schedules, and improved adherence to schedules. Specific ways to improve speed and reliability include establishing priority for transit vehicles at traffic signals, creating bus-only lanes, and using automatic vehicle location and control (AVLC) systems. Many of the agencies surveyed are planning or implementing such measures. More than three-quarters of respondents are planning or implementing changes to traffic signals. For example, the Utah Transit Authority initiated a new BRT line in 2008 that includes signal timing. BART encourages local jurisdictions to consider signal priority for surface transit, though the transit agency does not control such decisions. More than two-thirds of agencies surveyed are planning or implementing bus-only lanes. One agency, Sacramento Regional Transit District, is implementing queue jump lanes to allow buses to bypass general traffic at intersections.

Measures to improve the speed and reliability of transit need not require changes to operating systems and infrastructure. Even improved enforcement of traffic regulations can speed up travel times. For example, the San Francisco Municipal Transportation Agency (SFMTA) recently conducted an experiment on parking enforcement on one bus corridor. By intensifying parking enforcement at bus stops, as well as ensuring full availability of drivers and vehicles for all scheduled runs, on-time performance on the route improved from 81% to 88% (*27*). Yield-to-bus laws, which oblige drivers to give the right-of-way to buses entering traffic, also improve bus travel time, especially during peak hours. The states of California, Washington, Oregon, and Florida all have yield-to-bus laws in place (*28*).

In addition to attracting more riders, preferential treatments for buses also reduce emissions from buses by reducing the time spent idling at traffic lights or waiting to enter traffic. A study in Southampton, England, found that bus signal priority systems reduced CO_2 emissions from buses by 13%. On the other hand, preferential treatments for buses tend to cause additional delay for general traffic. The study found that CO_2 emissions from other traffic increased by 6%. The net effect of the system was to increase CO_2 emissions by 3% (*29*). A forthcoming TCRP Synthesis will report on the costs and benefits of transit preferential treatments in U.S. transit systems.

Agencies can make bus service more convenient for passengers through flex-routing. Flex-routing allows buses to deviate from their fixed routes a short distance (around three-quarters of a mile) to pick up and drop off passengers. Passengers can reserve stops in advance through a real-time reservation system. The OmniLink bus in Prince William County, Virginia, is an example of a flex-route bus. OmniLink uses advanced global positioning system (GPS) technology to ensure that buses remain on schedule. Flex-routing allows the OmniLink to provide transit access to a larger area, and it is more cost-effective than running both traditional bus services and paratransit services (*30*).

Transit Information, Promotion, and Incentives

Providing more and better information on transit educates potential transit users and also makes transit more convenient to use. Both information provided in advance and real-time information can increase ridership. Transit agencies can conduct outreach and provide a variety of incentives for people to take buses and trains instead of driving.

A TCRP study assessed the impact of transit information and promotion on transit users. Strategies assessed included the following:

- *Mass Market Information*—Develops awareness of various services available among the general population. Information can be broadcast in newspapers and on the radio, television, and billboards.
- *Mass Market Promotion*—Goes a step beyond mass market information by including incentives such as free or reduced fares.
- *Targeted Information*—Targets particular types of transit users or potential transit users. Information can be distributed by direct mailing, brochures, local newspapers, and other techniques.
- *Targeted Promotion*—Goes a step beyond targeted information by including incentives such as free or reduced fares.
- *Ongoing Customer Information*—Includes bus stop signs, telephone information services, and Internet sites. For example, many transit agencies are adding online trip planning software to their websites, which assists transit users in determining the best routes and timing for their transit trips.
- *Real-Time Transit Information*—Delivers real-time arrival times, information on delays, and other information through changeable message signs, telephone, or websites. This information allows riders to plan their trips more precisely.

Very little information is available on the effectiveness of these strategies at increasing ridership. Transit agencies typically find it too difficult or too costly to track riders' responses to individual initiatives (*31*).

Incentives to use transit include reduced fares and more convenient payment options. A TCRP study assessed the impact of changes to transit prices and fares on transit ridership. Strategies assessed included the following:

- *Changes in General Fare Level*—Increases or decreases in average transit fares.
- *Changes in Pricing Relationships*—Institutes discounts for various fare categories including multiple-ride tickets, off-peak travel, and tickets for senior citizens.
- *Changes in Fare Categories*—Adds new types of fares such as multiple-ride tickets and unlimited-ride passes.
- *Changes in Fare Structure Basis*—Includes flat fares, zone-based fares, or distance-based fares.
- *Free Transit*—Eliminates transit fares altogether.

The study finds that bus ridership increases an average of 0.4% for each 1% decrease in fare. Rail ridership increases an average of 0.18% for each 1% decrease in fare. Changes in fare have roughly twice the impact on off-peak ridership as on peak ridership (*32*).

Some transit agencies offer transit benefits programs in conjunction with local employers. Such programs often include discounted monthly transit passes as an incentive for employees to use transit. A TCRP study of the effectiveness of transit benefits programs found that such programs generally increase transit ridership, although the effects of individual programs vary widely. Transit ridership typically increased between 10% and 50% at worksites after implementation of benefits programs. The cost implications of such programs for transit agencies are not well understood (*33*).

Alerting potential riders to the GHG benefits of taking transit is one way to promote transit use. Online calculators, including one available at www.travelmatters.org (developed through a previous TCRP project), help individuals calculate the impact they can have on their personal GHG emissions by taking transit. These calculators can be integrated into transit agencies' websites. For example, San Francisco's BART has added a GHG calculator to its online trip planning software (www.bart.gov).

TABLE 5
AGENCIES PURSUING STRATEGIES TO INCREASE VEHICLE PASSENGER LOADS (% of 41 respondents)

Strategy Types	Planning	Implementing	Planning or Implementing
Transit marketing campaigns	56%	71%	85%
Provision of real-time transit information or trip planning software	59%	44%	83%
Improved transit shelters and station stops	54%	51%	83%
Improved transit access for bicycles and pedestrians	46%	61%	76%
Improved transit access for the disabled and elderly	44%	56%	73%
Improved vehicle comfort	41%	41%	61%
Service improvements; e.g., timed transfers, reduced travel times, improved modal integration	56%	37%	71%
Changes in fare structures or payment methods	39%	44%	63%
Safety improvements	41%	41%	59%
Optimization of existing routes and services	51%	56%	76%
Other strategies	5%	2%	5%
Any strategy			93% (38 agencies)

Optimizing Transit Routes

Agencies can make better use of their existing service by optimizing routes to increase the efficiency of service and focus service in corridors with a higher ridership potential. Individual transit agencies may find that they can selectively cut underutilized service to reduce net GHG emissions, but the GHG impacts of service cuts depend on the broader network effects of reducing transit service. Early morning bus service may be GHG inefficient, whereas peak and midday bus services are highly utilized and are much more GHG efficient than auto travel. However, just as extended service hours can increase ridership on peak services (see Extending Operating Hours in this chapter), reducing off-peak service can decrease peak ridership. Other key services that transit provides, such as access to jobs, may be compromised by a reduction in off-peak service. Agencies may be able to reduce the cost and improve the efficiency of services without cutting service altogether by using smaller vehicles on less heavily traveled routes.

A systemwide optimization of transit service can increase overall ridership levels without changing the total supply of service. For example, SFMTA plans to reconfigure its service routes beginning in 2009. SFMTA predicts that shifting service from underused routes to the busiest corridors will increase ridership by 9% by 2015 without increasing operating costs (*34*).

Almost all survey respondents reported that their agencies were taking some steps to increase ridership or load factors on existing transit service. Table 5 summarizes the specific strategies that agencies are pursuing. Transit marketing campaigns, providing real-time transit information and trip planning software, and making improvements to transit stations and shelters were the most commonly cited strategies, but every strategy was cited by more than half of the respondents. On some highly used transit services, vehicles are already traveling with maximum passenger loads and have problems with overcrowding. Faced with this problem, BART is removing some seats from trains to accommodate more passengers on each vehicle.

Of the transit agencies taking steps to increase ridership or load factors, almost all are aware that these strategies can reduce transportation GHG emissions. Nearly half of these agencies noted that reducing GHG emissions was a factor in their decision to increase ridership or load factors. Three agencies—Montgomery County DOT, Sound Transit, and LACMTA—reported that GHG emissions were a principal factor.

STRATEGIES TO MITIGATE CONGESTION

Most transit strategies that mitigate congestion are the same strategies that increase ridership. Transit mitigates congestion primarily through travel mode shift, as removing private vehicles from roadways tends to reduce congestion. Transit agencies, in partnership with other local and regional agencies, sometimes implement mode shift strategies to relieve congested conditions in specific areas.

Transit agencies in eight urban areas have partnered with other local agencies and the U.S.DOT to reduce roadway congestion as part of U.S.DOT's Integrated Corridor Management pilot program. The eight urban areas are Dallas, Texas; Houston, Texas; Minneapolis, Minnesota; Montgomery County, Maryland; Oakland, California; San Antonio, Texas; San Diego, California; and Seattle, Washington. Making better use of existing transit capacity in the selected corridors, and improving transit service through intelligent transportation system strategies will relieve both routine congestion and congestion related to roadway incidents, construction, and special events. Specific transit strategies included in the pilot programs will expand transit service, reduce transit travel times, provide real-time transit information, and provide incentives to use transit (*35*).

The impact of transit service on congestion is demonstrated in statistical analyses. A 2004 study found that congestion costs in a city decline as rail transit mileage expands, but that congestion costs tend to increase as bus mileage expands (*36*). Another study, comparing cities of similar sizes, found that cities with larger rail systems tend to have lower congestion costs (*37*). A third study found that growth in congestion slowed in Baltimore, Sacramento, and St. Louis after rail service began (*38*). The congestion impacts of individual transit services and changes to service will depend on such factors as existing levels of congestion and passenger load factors on vehicles.

Thirty-six of 41 agencies surveyed said that they are planning or implementing strategies that can reduce congestion on roadways. Most are aware that such strategies can reduce GHG emissions, and almost half said that reducing GHG emissions is a factor in their decision to pursue such strategies. Sacramento Regional Transportation District noted that, although GHG emissions were a factor in its pursuit of preferential treatments for transit vehicles, the main goals were to increase ridership and reduce congestion. Five agencies—Montgomery County DOT, Southwest Ohio Regional Transit Authority, TransLink, Sound Transit, and LACMTA—listed reducing GHG emissions as a principal factor for pursuing strategies that help to reduce congestion.

STRATEGIES TO PROMOTE COMPACT DEVELOPMENT

The mere presence of transit in a region may promote more compact development patterns, but transit agencies can play an active role in facilitating compact development patterns. Indeed, compact development patterns are best planned in conjunction with transit service. Transit agencies can promote TOD around their transit stations. Metropolitan planning organizations (MPOs), city and county governments, and developers also have roles to play in establishing compact developments complementary to transit.

Transit agencies can establish TODs on property they own surrounding transit stations and major transit nodes. BART developed a TOD on surplus agency-owned property at its Fruitvale station in Oakland, California. BART originally proposed to use the land for parking to increase the number of park-and-ride commuters, but plans were abandoned because of objections from the local community. In cooperation with community stakeholders, BART eventually developed a TOD on the property that incorporates retail, affordable housing, and public space (*39*) (see Figure 10). BART has several more TOD projects now in various stages of construction.

FIGURE 10 BART's Fruitvale TOD (*Source*: BART)

WMATA has a joint development program to support TOD. The program markets properties owned by WMATA to developers with the aim of promoting developments that reduce dependency on automobiles, increase the share of trips made by walking and biking, foster safe areas around stations, enhance connections to transit, and provide a mix of land uses. WMATA's Joint Development Policies and Guidelines establish the objectives and procedures of the program (*40*).

Transit agencies can contribute to other local planning efforts that promote TOD and compact development. These efforts include planning for individual sites as well as contributions to broader local and regional planning exercises, such as local comprehensive planning and regional land use and transportation visioning exercises. For example, the Santa Clara Valley Transportation Authority (VTA) in San Jose, California, fosters compact TOD through its Development Review Program. VTA works with cities in the region to ensure that individual projects will be compatible with existing and proposed transit services. VTA also has an outreach program that promotes compact development through local planning exercises (*41*).

Strategies to promote compact development differ from most of the other strategies discussed in this chapter in that transit agencies typically have no capacity to implement these strategies on their own. Transit agencies do not have control over land use and typically do not develop residential and commercial properties. Therefore, coordination with other public and private agencies is necessary to achieve any direct impact on development patterns.

Almost three-quarters of survey respondents are either planning or implementing strategies to promote compact development patterns or TOD complementary to their transit services. Table 6 summarizes the survey responses. All of these agencies said that they are coordinating their own service planning with broader local or regional development decisions. Most are engaging in planning exercises for specific transit stations. One agency, Sacramento Regional Transit District, is developing TOD guidelines.

TABLE 6
AGENCIES PROMOTING COMPACT DEVELOPMENT (% of 41 respondents)

Strategy Types	Planning	Implementing	Planning or Implementing
Station area planning (TOD)	54%	39%	59%
Coordination with local/regional development decisions	61%	44%	71%
Other strategies	0%	2%	2%
Any strategies			70% (28 agencies)

All agencies taking steps to promote compact development patterns or TOD complementary to transit services are aware that these strategies can reduce GHG emissions. Half of these agencies indicated that reducing GHG emissions was a factor in their decision to promote compact development. Sarasota County Area Transit characterized its efforts to promote compact development as part of the county's efforts to promote sustainability. Five agencies—Montgomery County DOT, Sound Transit, LACMTA, Massachusetts Bay Transportation Authority, and San Francisco's BART—noted that reducing GHG emissions was a principal factor in promoting compact development patterns.

VEHICLE EMISSION REDUCTION STRATEGIES

Transit agencies have substantial opportunities to reduce GHG emissions from transit vehicles by making changes to transit vehicles, fuels, and operations. Alternative vehicle technologies and fuels have received particular interest in the transit industry, but conventional vehicles and fuels also can reduce vehicle emissions.

Alternative Vehicle and Fuel Technologies

For road-based transit systems, alternative fuel and vehicle technologies can significantly reduce the amount of GHG emissions per mile of vehicle travel. Nearly 80% of U.S. transit buses are powered by conventional diesel engines (see Figure 11). Conventional diesel-fired internal combustion engines are one of the most carbon-intensive technologies that buses can use. An average 40-ft diesel bus with a fuel economy of 3.5 mpg emits 6.5 lb of CO_2 per mile traveled (*3*). Alternative propulsion technologies currently available for transit buses include the following:

- *Compressed natural gas (CNG), liquefied natural gas (LNG), and propane/liquefied petroleum gas (LPG)*—Specially designed vehicles can burn these types of fossil fuels. CNG is the most commonly used in transit buses.
- *Biodiesel*—Biodiesel fuel, made from soy, cooking grease, or other sources, can be blended with conventional diesel and used in standard diesel buses. Some changes to maintenance procedures may be necessary.
- *Hydrogen*—Hydrogen is an emerging transportation fuel. A few transit agencies have hydrogen buses, typically for demonstration purposes.
- *Hybrid propulsion systems*—Hybrid systems generally supplement a diesel-fired engine with a battery and electric motor that recapture some energy from normal vehicle motion and braking. Electric motors can also be combined with bus engines that burn other types of fuels.
- *Electricity*—Electricity is typically drawn from overhead catenaries by trolley buses, but is also used in battery powered electric vehicles

TCRP is currently updating its *Guidebook for Evaluating, Selecting, and Implementing Fuel Choices for Transit Bus Operations*. The revised guidebook will include basic information on the life-cycle GHG impacts of various alternative fuels and on the cost of various fuels.

Electricity differs from other fuel types in that emissions do not come from the transit vehicles themselves, but rather from the point at which the electricity is generated. Emissions depend on the source of electricity. Traditional fossil-fired generators release CO_2 emissions as they burn coal, oil, or natural gas. Other types of electricity generation, including nuclear, hydroelectric, wind, and solar, produce little or no GHG emissions in operation. The GHG emissions associated with electricity therefore depend on the specific mix of generation facilities. Transit agencies in regions of the country with relatively low-emitting electricity supplies, such as King County Metro in Washington State, benefit from lower electricity emissions. Some agencies make direct purchases of cleaner electricity from known generation sources, rather than using the standard mix from the local electricity grid. Although electricity is generally considered an alternative energy for transit, it is a standard power source for many rail-based transit systems, including light rail, subways, and some commuter rail systems.

The use of alternative fuels in transit vehicles has risen sharply in recent years, as shown in Figure 12. Use of electricity increased by 18% from 1995 to 2006. Use of CNG increased by a factor of 14 over the same period. Consumption of other alternative fuels also increased, in all cases more rapidly than consumption of diesel fuel, which grew by 8%.

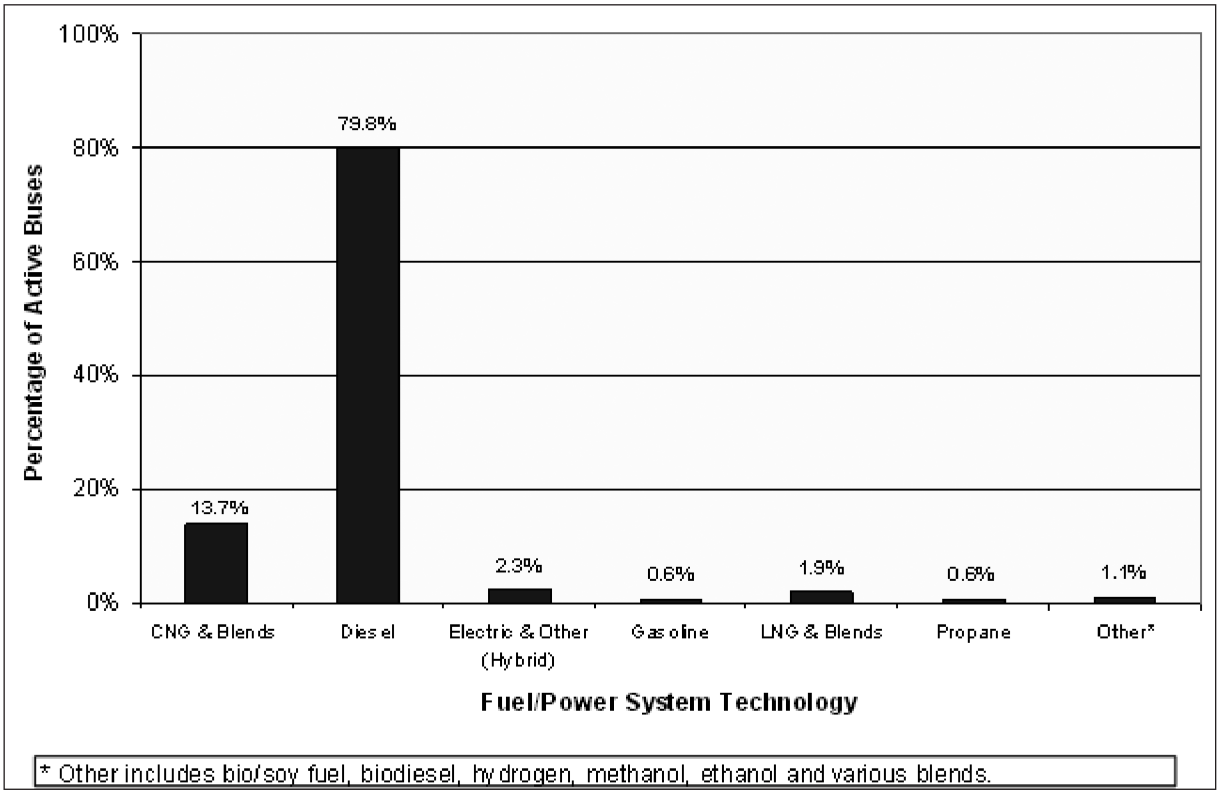

FIGURE 11 Distribution of active transit buses by fuel/propulsion system (*Source*: Neff, *2008 Public Transportation Fact Book, Part 2*: *Historical Tables*, APTA, Washington, D.C., June 2008).

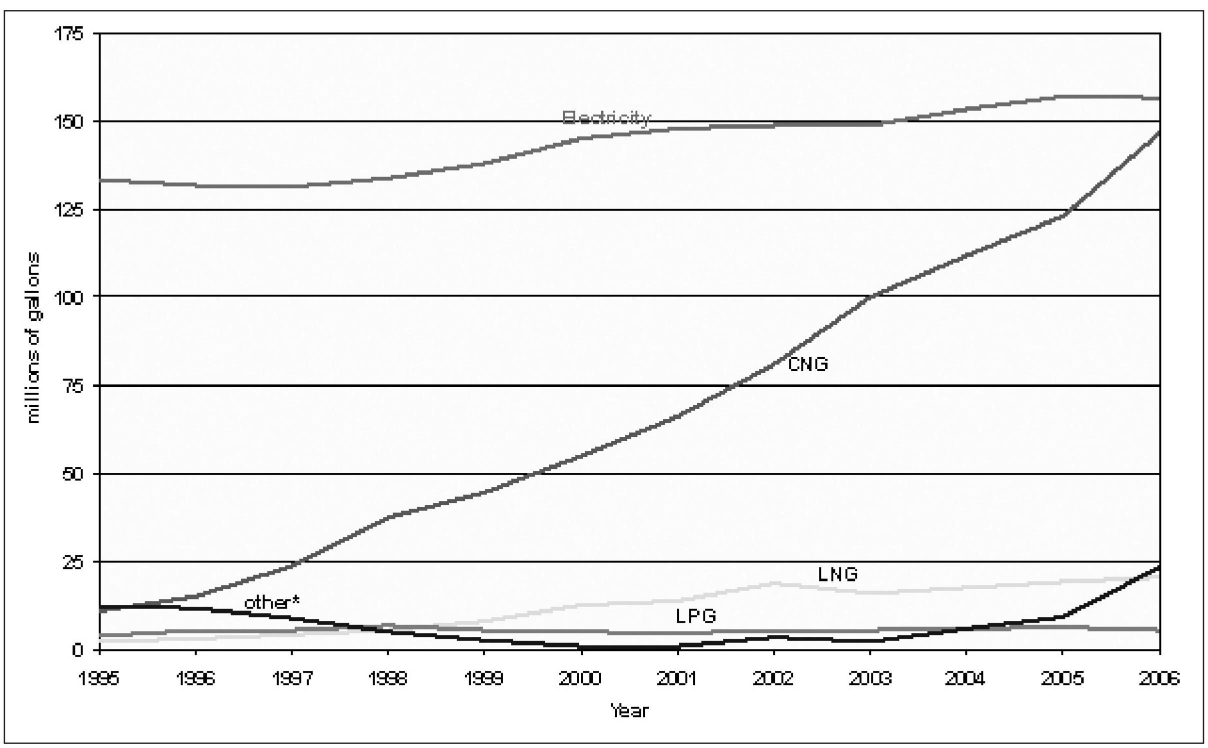

FIGURE 12 Alternative fuel consumption by transit vehicles, 1994–2006—millions of gallons (diesel equivalent) (*Source*: 2008 National Transit Database, Fuel consumption table, Federal Transit Administration).

The impact of alternative fuel and vehicle technologies on GHG emissions varies by fuel and vehicle type as well as by operating conditions. A number of studies have assessed the degree to which alternative bus propulsion technologies and fuels can reduce GHG emissions on a per mile basis. These studies typically analyze emissions across the full life cycle of the fuels, beginning with the production of fuel feedstock. Production of feedstock includes growing soybeans, in the case of most biodiesel, or extracting fossil fuels, in the case of diesel and CNG. Life-cycle assessment also accounts for emissions from the refining of fuels, transportation of fuels to the point of distribution, and combustion of fuel in vehicles. This type of assessment is also known as a "well to wheels" assessment.

A 2007 report commissioned by the California Energy Commission (CEC) contains the most comprehensive assessment to date of GHG impacts of alternative fuels in buses. That study compared a total of 13 vehicle and fuel combinations for buses in California. In addition, it assessed a number of fuel production pathways for each fuel type. The fuel pathway, or the process by which a fuel is produced, affects its life-cycle GHG emissions. For example, it takes less energy to produce biodiesel from canola than from soy. The origin and destination of fuels is also important. The farther feedstocks are transported, the higher are life-cycle emissions. The CEC report uses a number of assumptions specific to fuel consumption in California. The report assesses the impact of fuels in various future years, given expected improvements in vehicle technologies over time (*42*).

Table 7 summarizes the study's findings on the reduction in GHG emissions in urban buses using various alternative fuels. Electric vehicles provide the greatest reduction from conventional diesel, at 55% less GHG emissions per mile. (This figure assumes the average electricity generation mix in California.) A blend of 20% soy-based biodiesel with conventional diesel reduces GHG emissions the least of the options examined, at 12%. Note that results for individual transit agencies can vary based on a wide range of assumptions. For example, the electricity generation mix in a region has a substantial effect on the level of emissions associated with electric vehicles.

More recently, several studies have questioned the ability of a large-scale shift to biofuels to provide a net reduction in GHG emissions. Fuels produced from crops, including corn-based ethanol and soy-based biodiesel, cause some additional GHG emissions from the conversion of natural lands to agricultural lands. Fuels produced from waste products have an advantage in this regard. Taking conversion of natural lands into account, some studies have found that crop-based biofuels are responsible for more GHG emissions than conventional fuels (*43,44*). The data in Table 6 do not take these additional emissions from land use change into account.

TCRP Report 93 assessed the state of research and development of various alternative bus propulsion technologies as well as likely future trends in adoption. The report also examined the possibility of using lighter materials in buses to reduce the weight of the vehicle and improve fuel efficiency. Both Houston Metro and LACMTA have successfully experimented with lighter weight buses. By one estimate, the use of lightweight materials can reduce fuel consumption by one-tenth of a gallon per mile. The report found that the currently available technology in a hybrid-electric propulsion system burning diesel or biodiesel, installed in a lightweight composite fiber body, is a particularly promising option for low-GHG buses (*45*).

There is some uncertainty about the extent to which CNG buses reduce GHG emissions. The methane burned in these vehicles is also a GHG and, when released uncombusted, has a greater GWP than CO_2. An empirical trial by the Northeast Advanced Vehicle Consortium on year 2000 buses found that CNG buses produced higher GHG emissions on a simulated New York City duty cycle, as well as on a central business district cycle, than did diesel buses. Vehicle cycles in these areas include slower average travel speeds and more stopping and starting than cycles in other areas. Some models suggest that existing CNG buses produce little to no GHG benefit over conventional diesel buses; however, improvements to CNG bus technologies are expected to offer more substantial benefits in the future (*45*).

In rail transit, regenerative braking is the technology with the greatest potential to reduce energy consumption and thereby reduce GHG emissions. Regenerative braking systems on rail cars allow vehicles to capture energy as they slow or stop and store it for later use or transfer it to vehicles elsewhere in the system. Current technologies only allow the transfer of energy to nearby trains, but with technology improvements, trains should be better able to store energy on board (*45*). Both BART and NYMTA are exploring new regenerative braking technologies for their rail transit systems.

Almost all survey respondents are either currently using or planning to use alternative vehicles or fuels in their transit fleets. More than three-quarters are operating or planning to purchase hybrid electric vehicles. About one-third are operating or planning to purchase more fuel-efficient vehicles powered by conventional technologies, such as lightweight diesel buses. Another third are operating or planning to purchase electric vehicles. More than two-thirds of agencies are using or planning to use alternative fuels in transit vehicles. Biodiesel was the most common alternative fuel type cited by transit agencies, followed by CNG, electricity, and hydrogen. None of the agencies surveyed are pursuing or using LNG or LPG.

Agencies cited a variety of initiatives to use alternative vehicle technologies and fuels:

- SFMTA and TriMet currently fuel their entire bus fleets with biodiesel blends.
- SFMTA has a goal to convert its entire fleet to electric drive vehicles by 2020.

TABLE 7

REDUCTION IN LIFE-CYCLE GHG EMISSIONS AND PETROLEUM USE IN URBAN BUSES, COMPARED WITH DIESEL FUEL (Year 2012 Vehicles)

Fuel/Vehicle Type	Biodiesel (B20)	Liquefied Natural Gas (LNG)	Methanol	Hybrid Electric Vehicle	Compressed Natural Gas (CNG)	Fuel Cell	Electricity
Petroleum Reduction from Diesel	16%	100%	97%	20%	100%	100%	100%
GHG Reduction from Diesel	12%	16%	18%	20%	23%	24%	55%

Source: TIAX LLC, *Fuel Cycle Assessment: Well-to-Wheels Energy Inputs, Emissions, and Water Impacts*, California Energy Commission, 2007 (42) [Online]. Available: www.energy.ca.gov/2007publications/CEC-600-2007-004/CEC-600-2007-004-REV.PDF.

- AC Transit (Alameda–Contra Costa Transit District) uses gasoline hybrid buses.
- VTA is currently testing biodiesel in buses.
- RTD plans to use hybrid CNG–electric buses.
- Southwest Ohio Regional Transit Authority is considering biodiesel derived from palm oil, which may reduce GHG emissions more than typical soy-based biodiesel.
- Foothill Transit, a small agency in the Greater Los Angeles area, plans to convert its entire bus fleet to CNG and to test electric buses.

One challenge for some agencies in using alternative fuels is finding a sufficient supply of the fuel and finding funds to purchase alternative fuels, which sometimes can be more costly than conventional fuels. The affordability of alternative fuels can change from month to month with fluctuations in petroleum markets and markets for other fuels and feedstocks. Both King County Metro and TriMet report that their use of biodiesel has been constrained by cost factors. King County Metro is investigating long-term contracts with biodiesel providers to stabilize the volume and price of their fuel supply.

All agencies pursuing alternative vehicle or fuel technologies are aware of the impact that these strategies can have on transit vehicle emissions. Of those agencies operating alternative vehicle types, more than three-quarters cite reducing GHG emissions as a reason that vehicles were purchased, and more than one-third cite reducing GHG emissions as a principal factor (Montgomery County DOT, Southwest Ohio Regional Transit Authority, Jacksonville Transportation Authority, Community Transit, TransLink, Sound Transit, LACMTA, Transit Authority of River City, Lee County Transit, Hampton Roads Transit, Sarasota County Area Transit, Massachusetts Bay Area Transit Authority, and BART).

Of the agencies using or planning to use alternative fuels, again more than three-quarters cite reducing GHG emissions as a reason, and more than one-third cite reducing GHG emissions as a principal reason (Montgomery County DOT, Southwest Ohio Regional Transit Authority, LYNX, Jacksonville Transportation Authority, King County Metro, Council on Aging of St. Lucie, TransLink, Lee County Transit, Hampton Roads Transit, Sarasota County Area Transit, Palm Tran, and TriMet). King County Metro notes that it receives credit for use of biodiesel on the Chicago Climate Exchange.

Operations and Maintenance

Transit agencies can improve the fuel efficiency of their existing transit vehicles, and thereby reduce GHG emissions, largely by improving the operations and maintenance of vehicles. Operational strategies include the following:

- *Driver education*—Vehicle operators can be trained in fuel-efficient driving techniques, such as smoother acceleration and deceleration and avoiding vehicle idling. The Canadian Urban Transit Association's SmartDRIVER program has provided instruction on fuel-efficient driving to more than 100 transit system representatives (*46*).
- *Anti-idling policies or technologies*—Unnecessary idling of transit vehicles may occur at stations, stops, and maintenance yards. Technologies that automatically shut off vehicle engines after several minutes of idling, or policies that instruct drivers not to idle unnecessarily, can reduce fuel consumption. New Jersey Transit is reducing idling of diesel train engines by switching trains to electric power when in railyards.
- *Maintenance programs*—Routine vehicle maintenance programs can improve vehicle efficiency. Keeping bus tires properly inflated is one simple maintenance measure to improve fuel efficiency. In 2005, TriMet maintenance crews boosted gas mileage on buses by approximately 10% by adjusting transmissions, front-end alignments, and steering control arms, and maintaining a set tire pressure.
- *Vehicle retrofits*—In some cases, retrofits to existing vehicles may improve energy efficiency and reduce GHG emissions. For example, Palm Tran in Palm Beach County, Florida, is installing electric fan kits on bus vehicle engines to improve fuel efficiency. LACMTA is considering installing improved batteries on their CNG buses to reduce idling, and is converting some of its buses to run on electric power.

Other improvements to bus fleets and operations can improve fuel efficiency or reduce the amount of vehicle travel needed. GPS technologies on transit vehicles can help transit agencies optimize vehicle movements to reduce delay and fuel usage. Traffic signal preemption and queue jump lanes for transit vehicles also reduce idling (*46*). Additional strategies cited by survey respondents include the following:

- RTD has an intelligent shifting program for buses, specific to different topographical conditions, to maximize engine efficiency.
- The Sunshine Bus Company in St. Johns County, Florida, is switching to smaller vehicles to reduce energy consumption.
- Chicago Transit Authority is developing a model to measure and help minimize bus fleet operating costs and emissions.
- Sound Transit has a midday bus storage program; buses are stored close to the central business district between the morning and afternoon commutes to reduce deadhead mileage. This program reduces bus fuel consumption without changing the amount of service provided.

Agencies may be able to reduce GHG emissions through specific measures targeted at non-CO_2 gases. For example, fugitive emissions of CH_4 from CNG buses and of HFCs from air-conditioning systems also contribute to global warming. Adjusting maintenance procedures may reduce such emissions from transit vehicles.

Almost all agencies surveyed are pursuing some strategies that reduce emissions from existing transit vehicles. Table 8 summarizes survey responses. Nearly three-quarters of agencies surveyed are improving the fuel efficiency of their existing transit fleet by implementing anti-idling policies or technologies and by implementing vehicle maintenance programs. Nearly two-thirds are planning or implementing driver education programs. Almost half of the agencies surveyed are planning or implementing vehicle engine retrofits to improve the fuel efficiency of their transit fleet. More agencies are in the implementation phase rather than the planning phase of these strategies.

TABLE 8
AGENCIES PURSUING VEHICLE OPERATION AND MAINTENANCE STRATEGIES (% of 41 respondents)

Strategy Types	Planning	Implementing	Planning or Implementing
Anti-idling policies or technologies	29%	63%	73%
Vehicle maintenance programs	22%	66%	76%
Vehicle engine retrofits	24%	24%	44%
Driver education	27%	44%	61%
Other strategies	17%	20%	29%
Any strategies			90% (37 agencies)

Almost all agencies pursuing these strategies are aware that they can reduce GHG emissions. More than two-thirds responded that reducing GHG emissions is a factor in their agency's decision to pursue fuel-efficiency strategies. Ten agencies indicated that GHG emissions are a principal factor in their agencies' decisions to pursue fuel-efficiency improvement strategies for their existing transit fleet (BART, Community Transit, Hampton Roads Transit, LACMTA, Lee County Transit, Montgomery County DOT, Sarasota County Area Transit, Sound Transit, Southwest Ohio Regional Transit Authority, and TransLink). A few agencies noted that reducing operating costs and complying with environmental regulations are key factors in pursuing these strategies.

STRATEGIES TO REDUCE EMISSIONS FROM CONSTRUCTION AND MAINTENANCE

Construction of facilities and infrastructure, as well as maintenance of facilities, infrastructure, and transit vehicles, is a source of GHG emissions. While these activities probably represent a small share of transit agencies' total emissions, they can nonetheless be improved to shrink agencies' GHG emissions. The strategies discussed in this section apply generally to any industry that provides infrastructure services. There has been little research to date on how these strategies apply to transit agencies specifically. Still, a number of agencies are implementing or planning these types of strategies.

Agencies can reduce GHG emissions from construction and maintenance in three primary ways:

- *Reduce emissions embodied in any materials used*—This strategy typically involves changing the types of materials used or the source of materials used. Often, recycled construction materials have lower embodied emissions, because the energy required to reprocess waste materials is less than that required to process virgin materials. For example, both BART and NYMTA are planning to use rail ties made from recycled materials in future construction and maintenance. Recycled plastic can be incorporated in bus shelters, benches, and signposts. Fly ash can be substituted for a portion of the portland cement that typically goes into concrete to reduce GHG emissions. Materials drawn from local sources require less energy to transport than materials drawn from farther away. Transit agencies can contribute to lowering overall GHG emissions from the construction industry by recycling waste from their own construction activities.
- *Reduce emissions from on-road transportation of materials, construction workers, and waste*—Any measures that reduce the amount of materials and waste transported will reduce GHG emissions. Use of biofuels in heavy-duty vehicles that transport materials

and waste also can reduce GHG emissions. Emissions from transportation of construction workers can be reduced by implementing carpooling plans or encouraging workers to use transit.

- *Reduce emissions from construction and maintenance equipment*—Construction equipment and maintenance vehicles also typically burn fossil fuels that release GHG emissions. The same types of strategies that can reduce emissions for transit vehicles, including using biofuels and reducing idling, also can reduce GHG emissions from construction and maintenance equipment. If transit agencies use contractors for construction and maintenance work, these types of strategies may be more difficult to control.

Portland's TriMet has instituted a number of sustainable construction practices for a light-rail extension, the Interstate MAX Yellow Line. These practices will help reduce GHG emissions, and many also save money for the agency. Practices include the following:

- *Plastic railroad ties*—TriMet installed 6,000 plastic ties made of recycled automobile gas tanks, instead of steel (see Figure 13).
- *Plastic bollards*—Interstate MAX is the first light-rail line to use recycled plastic bollards, instead of reinforced metal stanchions, in the paved trackway. The recycled bollards saved $100,000 in purchasing costs over steel, and saved an additional $150,000 in installation costs.
- *Using existing materials*—TriMet pioneered an innovative practice of using the existing road-base concrete and adding a new layer of asphalt. This reduced demolition, trucking, and disposal fees by nearly $2.4 million.
- *Recycling pavement and track*—Where the existing road base could not be reused, TriMet used recycled asphalt and concrete as base materials, recycling enough material to cover a 50-ft wide strip, 5 mi long and 1.5 ft deep. These measures resulted in savings of $186,000 by buying recycled materials instead of new materials.

FIGURE 13 Recycled plastic railroad ties used in construction of TriMet's Interstate MAX Yellow Line.

Almost three-quarters of agencies surveyed are planning or implementing strategies to reduce energy consumption or GHG emissions from construction and maintenance (see Table 9). Nearly two-thirds of agencies surveyed are taking steps to recycle construction waste. Half are taking steps to use alternative construction materials. About one-third of agencies surveyed are investing in changes to their construction equipment, vehicles, or fuels. More than a quarter are using locally sourced materials. One agency, the Utah Transit Authority, is developing a sustainability design standards program to maximize use of recycled materials in construction.

TABLE 9

AGENCIES PURSUING CONSTRUCTION AND MAINTENANCE STRATEGIES (% of 41 respondents)

Strategy Types	Planning	Implementing	Planning or Implementing
Use of alternative fuels/technologies in non-revenue vehicles	20%	29%	44%
Changes to construction equipment, vehicles, or fuels	20%	17%	32%
Changes to construction materials	0%	0%	0%
Use of alternative construction materials	27%	29%	49%
Recycling construction waste	29%	39%	61%
Sourcing materials locally	10%	17%	27%
Changes to construction equipment/vehicles or fuels	0%	0%	0%
Other strategies	5%	5%	7%
Any strategies			73% (30 agencies)

All of the agencies planning or implementing these measures are aware that they can reduce GHG emissions. More than two-thirds noted that reducing GHG emissions is a factor in their agency's decision to pursue these strategies. Almost one-third of agencies indicated that reducing GHG emissions was a principal factor in their decision (Southwest Ohio Regional Transit Authority, Jacksonville Transportation Authority, Community Transit, TransLink, Sound Transit, LACMTA, Hampton Roads Transit, Sarasota County Area Transit, Foothill Transit, and TriMet). Sacramento Regional Transit District noted that reducing life-cycle costs was the primary driver of its construction and maintenance strategies.

OTHER ENERGY-EFFICIENCY AND RENEWABLE ENERGY MEASURES

Other energy-efficiency measures can reduce emissions from transit agencies' facilities and administrative functions. Agencies can reduce energy consumption in office buildings, stations, shelters, and maintenance yards through a variety of energy-saving measures. These include changes to lighting, heating, and cooling systems in existing facilities, as well as building new facilities to a higher standard of energy efficiency. Recycling waste from office buildings, especially paper, can also help to reduce GHG emissions. Nonrevenue vehicle fleets can incorporate alternative fuels and technology to reduce emissions. Transit agencies can offer programs for employees to reduce their own emissions from their commutes by taking transit themselves or by carpooling.

Thirty-four of 41 respondents are planning or implementing strategies to reduce energy consumption and/or GHG emissions from their facilities and administrative functions. Table 10 summarizes survey responses. Three-quarters of respondents are either planning or implementing strategies to reduce the energy used in their office buildings. Almost two-thirds of respondents are pursuing strategies to reduce emissions from employee commuting and the energy used in maintenance yards. About half noted that they are working to reduce employee travel.

TABLE 10
AGENCIES REDUCING EMISSIONS FROM FACILITIES AND NON-REVENUE VEHICLES (% of 41 respondents)

Emissions Source	Planning	Implementing	Planning or Implementing
Employee commuting	20%	49%	61%
Employee travel	15%	34%	44%
Energy used in office buildings	41%	56%	76%
Energy used in maintenance yards	37%	39%	63%
Other	5%	5%	10%
Any strategies			83% (34 agencies)

Almost all agencies pursuing such strategies are aware that their efforts can reduce GHG emissions. Three-quarters indicated that reducing GHG emissions was a factor in their agency's decision to pursue these reduction strategies. Reducing GHG emissions was a principal factor for almost a quarter of these agencies (Montgomery County DOT, Southwest Ohio Regional Transit Authority, Jacksonville Transportation Authority, Sound Transit, LACMTA, Hampton Roads Transit, Sarasota County Area Transit, and Foothill Transit). Both Sacramento Regional Transit District and Chicago Transit Authority cited cost savings as the primary driver for implementing such strategies.

Specific energy-saving strategies being pursued include certification of facilities under the Leadership in Environmental Design (LEED) standard, a widely used green-building and energy-efficiency design standard. Many agencies already have LEED-certified buildings or policies requiring LEED certification of new buildings:

- WMATA has a policy goal of LEED Silver certification for all new buildings and major renovations.
- Sacramento Regional Transit District consolidated its headquarters into a LEED-certified building.
- King County Metro is pursuing LEED Silver certification or better for any new construction.
- Lee County Transit will use LEED construction guidelines for a new facility.
- LACMTA plans to adapt the operation and maintenance of its existing buildings according to LEED principles.

Another option for transit agencies is to increase the amount of electricity they use from renewable sources. Renewable energy, including solar, wind, and tidal energy, has a much lower GHG impact than energy generated from burning fossil fuels. Transit agencies can install renewable energy infrastructure on their own property and can purchase more of their electricity from renewable sources. Individual solar cells can be used to power lighting for bus shelters, information signs, and emergency telephones. Some agencies, including LA Metro, have installed solar photovoltaic cells on the roofs their buildings. Community Transit in Washington State is incorporating solar panels in its new facilities. The Massachusetts Bay Transportation Authority is considering building sources of renewable energy to power its transit facilities. Other initiatives to reduce GHG emissions from administrative functions include the following:

- Utah Transit Authority installed timers for lights in park-and-ride facilities to reduce consumption of electricity.
- Chicago Transit Authority retrofitted lighting in buildings to reduce energy consumption. The agency also uses flex-fuel nonrevenue vehicles, which can burn alternative fuels.
- In 2008, King County Metro significantly expanded its outreach programs to help employees reduce their energy consumption.
- BART and New Jersey Transit use hybrid vehicles in their nonrevenue fleets.

A report commissioned by the FTA will supplement current knowledge on strategies to reduce emissions from transit agencies' operations. The Transit Greenhouse Gas Emissions Management Compendium will guide transit managers in planning and decision making. The compendium will cover strategies to reduce emissions from operations, maintenance, and construction. The compendium will provide information on the scale of emissions reductions possible and typical costs of strategies. It will include an emissions profile of a transit agency, as well as case studies of strategies implemented by agencies.

GREENHOUSE GAS EMISSIONS IN DECISION MAKING

Transit agencies may implement strategies that reduce GHG emissions for many other reasons than reducing GHG emissions. Many of the strategies discussed provide important customer service benefits, compliance with existing environmental regulations, and cost savings. Reducing GHG emissions should not be seen as the only or principal reason to undertake such strategies, but rather one of many co-benefits. GHG emission reductions alone typically are not sufficient to justify pursuing such strategies under current agency planning practices and constraints. In addition, some strategies may provide no net benefit to GHG emissions, but may be important for other reasons. Buses that serve disadvantaged neighborhoods may have low passenger loads and therefore emit more GHGs than they save, but they provide a valuable social service nonetheless.

In planning and implementing strategies, agencies considered GHG emissions benefits to different degrees. Figure 14 compares the role that GHG emissions played in various types of strategies. Strategies are grouped together depending on whether they primarily reduce emissions from the transportation sector as a whole or reduce emissions from transit agencies.

GHG emissions were a principal factor in decision making more often for strategies that reduce agencies' emissions than for strategies that reduce emissions from the transportation sector. GHG emissions were a principal factor most frequently in decisions to use alternative fuels. GHG emissions were a principal factor least frequently for strategies that increase vehicle passenger loads. This result probably reflects the central role that increasing passenger loads plays in achieving traditional goals of transit agencies.

GHG emissions were more likely to play even a small role in decision making for strategies that reduce agencies' emissions than for strategies that reduce emissions from the transportation sector. Approximately half of agencies said that GHG emissions were a factor or a principal factor in decisions to pursue strategies to expand service, increase vehicle passenger loads, mitigate congestion, and promote compact development. Upwards of two-thirds of agencies said that GHG emissions were a factor or a principal factor in pursuing alternative fuels or vehicles, vehicle operations and maintenance strategies, construction and maintenance strategies, and other energy-efficiency and renewable energy strategies. Awareness of the GHG impacts of strategies was very high among agencies planning or implementing strategies. For every strategy type, nearly all agencies were at least aware of the potential impacts on GHG emissions.

EFFECTIVENESS OF TRANSIT STRATEGIES

Transit strategies' effectiveness at reducing GHG emissions depends on the design of strategies and the context of regional transportation systems. Several recent studies have quantified the potential impact of broad transit strategies on

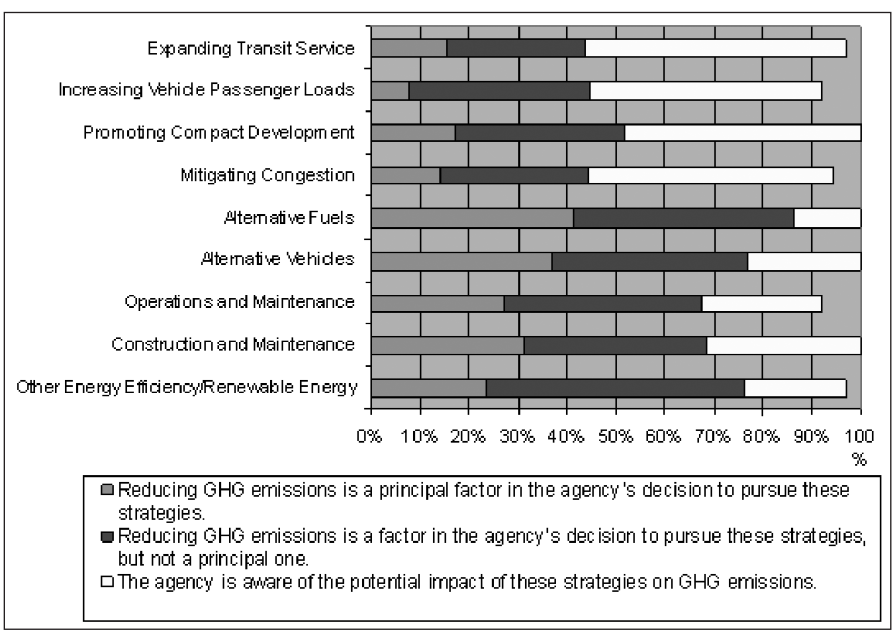

FIGURE 14 GHG emissions in decision making (percent of agencies planning or implementing each strategy type) [*Source*: ICF analysis (unpublished)].

GHG emissions, and more studies are ongoing. These studies generally have found that transit strategies would reduce transportation GHG emissions at both the state and national levels, and have highlighted some key factors in determining strategies' net impact on GHG emissions.

Many states have undertaken their own research on strategies to reduce transportation GHG emissions, including transit strategies, as part of climate action plans. Plans from a sample of five different states have estimated the potential of those polices to reduce GHG emissions at between 0.2 and 5.8 $MMtCO_2e$ per year in 2020 (*47*). For comparison, all transportation emissions from the state of Delaware total 5.4 $MMtCO_2e$ per year (*8*). Results vary by state depending on analysis techniques, the size of the state, existing urban development and transportation patterns, and the aggressiveness of policies proposed. A 2008 study by the University of Minnesota found that comprehensive transit and smart growth policies will be essential to meeting Minnesota's goal to reduce GHG emissions 15% below 2005 levels by 2015. The study found that construction of an extensive LRT or BRT network in the Twin Cities region could reduce statewide vehicle-miles traveled (VMT) by 2.2% in 2025. Improvements to the region's existing transit system could reduce statewide VMT by 0.3% (*48*).

ICF International recently estimated the GHG impacts of a package of bus transit improvements for Washington's Climate Action Plan. The scenarios considered as part of the analysis included a doubling of transit ridership, an increase in vehicle load factors, and a shift toward the use of hybrid buses. The analysis found that the benefits of reduced VMT from increased transit ridership in Washington may be offset by an increase in emissions from an expanded diesel bus fleet. As shown in Figure 15, the net effect on GHG emissions depends on assumptions for improvements in bus productivity (load factors) and bus fuel economy (through the introduction of diesel hybrids). Expanding the transit fleet without increasing load factors or using cleaner vehicle technologies would produce a net *increase* in GHG emissions. Converting the bus fleet to 75% diesel hybrids would generate a net decrease in emissions. Simultaneously increasing load factors would reduce emissions even further.

Several national studies are investigating the potential of various transportation strategies, including broad transit strategies, to reduce GHG emissions. Three studies will be released in 2009:

- *Moving Cooler*, a forthcoming report from the Urban Land Institute, will investigate strategies that could be implemented to reduce GHG emissions from personal travel. Improvements in public transportation are one category of strategies that the work will assess. The project does not address technology-based strategies for vehicles and fuels. Individual measures and bundles of strategies will be analyzed for their cost-effectiveness in reducing GHG emissions.
- A study for TRB, *Potential Energy Savings and Greenhouse Gas Reductions from Transportation*, is reviewing policies and strategies to affect behavior and improve fuel economy for passenger and freight vehicles across all modes.
- A study for the U.S.DOT is being completed in coordination with the EPA and the U.S. Global Change Research Program. The report will summarize transportation's impact on climate change and strategies to reduce the impact. It examines the GHG reduction effects of alternative transportation strategies, and the potential fuel savings and reductions in air pollution associated with these strategies.

Generally transit plans, whether they are for individual stations, corridors, or entire systems, will include a range of the strategies described in this chapter. The GHG impact of plans depends on the net effect of many elements. A bus expansion plan might include elements to increase the provision of bus service, increase ridership, and switch to more fuel-efficient buses. Strategies must be evaluated concurrently to determine their composite effects on transportation GHG emissions. For example, a BRT system can reduce greenhouse gas emissions by—

- Using newer, more fuel-efficient high-capacity buses;
- Drawing more riders out of their cars and onto faster, more convenient transit;

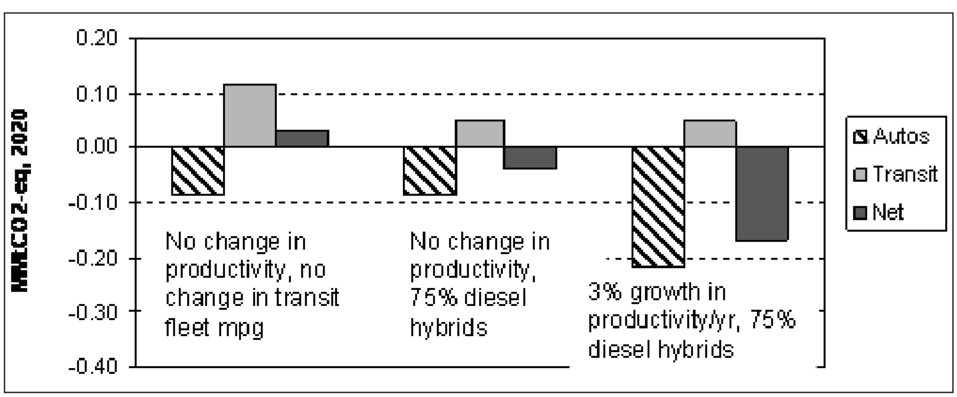

FIGURE 15 GHG impacts of transit expansion scenarios in Washington State, 2020.

- Capturing operational efficiencies through dedicated lanes and signal timing, as well as centrally managed dispatching; and
- Potentially switching to low carbon alternative fuels (*49*).

Chapter five describes techniques to analyze the impact of transit on GHG emissions through mode shift, reduced congestion, compact development, and reductions from transit vehicles and agency operations.

CHAPTER FIVE

ESTIMATING GREENHOUSE GAS SAVINGS FROM TRANSIT

Transit agencies can estimate both the impacts of entire transit systems on GHG emissions and the marginal impacts of specific strategies on GHG emissions. Impacts of systems generally can be quantified using existing data and analysis techniques. Estimating the impact of specific transit strategies is more complex in some cases. This chapter provides an overview of analysis frameworks and some agencies' experiences with quantification, as well as references to more detailed calculation methodologies.

Several recent studies have provided methodologies for calculating the GHG impacts of transit service. The most robust of these is a methodology developed by APTA's Climate Change Standards Working Group and funded by FTA. The methodology, *Recommended Practice for Quantifying Greenhouse Gas Emissions from Transit*, was released in 2009. This chapter draws heavily on that document. More detail on many of the calculation methodologies described here is available within APTA's methodology (*50*).

Quantifying the impacts of transit systems and of transit strategies on GHG emissions is a relatively new effort. For years, state DOTs, MPOs, and transit agencies have estimated the impact of transit strategies on criteria pollutants, as required by the Clean Air Act; however, there is no regulatory requirement to estimate the impacts of transit on GHG emissions. Still, transit agencies may find it useful to quantify impacts on GHG emissions for the following purposes:

- Reporting to the Climate Registry and other agencies
- Preparing for possible state and federal reporting requirements (e.g., Washington State is currently developing a rule that will require reporting by any agency that operates an on-road vehicle fleet that emits at least 2,500 metric tons of GHG annually).
- Supporting internal efforts to reduce emissions
- Communicating the benefits of transit to the public and to legislators
- Ensuring eligibility for new funding sources
- Preparing for the implementation of new state GHG regulations, such as California's SB 375, which requires MPOs to plan for reduced GHG emissions from light-duty vehicles
- Preparing for possible new federal regulations.

Analyses can include any of the six GHGs listed in Table 11. Within analyses of GHG emissions from transportation, CO_2 is the most commonly analyzed gas, accounting for 95% of U.S. transportation GHG emissions (*5*). Emissions of CO_2 are typically the easiest to calculate. CH_4 and N_2O are also commonly included in calculations. The remaining gases are less commonly included, although estimates of these are required by some registries.

TABLE 11
TYPICAL SOURCES OF EMISSIONS

Gas	Typical Sources for Transit Agencies	Global Warming Potential (GWP)
Carbon dioxide (CO_2)	Gasoline and diesel combustion Combustion at stationary sources; e.g., maintenance yards Electricity purchases	1
Methane (CH_4)	Gasoline and diesel combustion Fugitive emissions of natural gas	21
Nitrous oxide (N_2O)	Gasoline and diesel combustion	310
Hydrofluorocarbons (HFCs)	Leakage of refrigerants	12–11,700
Perfluorocarbons (PFCs)	Leakage of refrigerants	6,500–9,200
Sulfur hexafluoride (SF_6)	Leakage from electrical equipment	23,900

Source: *Recommended Practice for Quantifying Greenhouse Gas Emissions from Transit*: *Draft*, APTA Climate Change Standards Working Group, Mar. 2008, p. 16 (50).

Analyses of transit's impact on GHG emissions can include any of the four components discussed in chapter three. Transit displaces emissions through travel mode shift, compact development, and reduced congestion. Transit produces emissions from vehicles, facilities, and construction and maintenance (see Figure 5 for a diagram of components). Analyses of individual transit strategies incorporate emissions produced by transit vehicles and emissions displaced by transit to measure the net impact of strategies. Emissions displaced include, at a minimum, the impact of travel mode shift. To provide a more complete account of displaced emissions, the benefits of reduced congestion and compact development may be included in an analysis of strategies. These components have more often been included in analyses of the impacts of transit systems than in analyses of transit strategies.

The following sections describe proposed and commonly used methods for estimating each of the four components of analysis. These techniques generally can be applied to individual transit projects or strategies, to entire transit agencies, or to an aggregate of all transit service in a state or the United States. The basic analytical principles are the same at each level, although the specific techniques for data gathering and forecasting vary.

TRAVEL MODE SHIFT

To estimate the impact of mode shift to transit, transit agencies must determine how many private vehicle trips are displaced by trips on buses and trains. Some trips on transit remove private vehicles from the road. Other trips made on transit would have been made by carpool, walking, biking, or not made at all, if transit were not available.

There are three general approaches to estimating the mode shift effect for a given transit agency. First, agencies can use regional travel demand models that predict trip patterns based on transportation networks, land uses, and other factors. MPOs typically maintain the travel demand model for a region. Using a travel demand model to calculate mode shift is relatively labor intensive. In addition, many urban areas' travel demand models do not include a robust methodology for calculating transit trips and are therefore inadequate for this type of analysis.

A second approach uses evidence from "natural experiments." For example, where transit service has been temporarily eliminated by strikes or power outages, the empirical impacts on VMT can inform an estimate of travel mode shift.

A third approach applies a mode shift factor to data on the transit agency's passenger mileage. APTA's methodology recommends this approach. A mode shift factor is a ratio of transit passenger trips to displaced private auto trips. For example, a mode shift factor of 0.5 means that for every 100 trips made on transit, 50 vehicle trips are avoided. Locally appropriate mode shift factors can be estimated using outputs from a regional travel demand model or from rider surveys. In the absence of these types of information, agencies can use average mode shift factors available in APTA's methodology. Mode shift factors are provided for various sizes of transit agencies.

Applying the mode shift factor to the total number of passenger trips, agencies can calculate the number of vehicle trips they displace. Typically, analyses assume that the average trip length for transit trips and for displaced vehicle trips will be the same. The impact of displaced vehicle trips on GHG emissions is then estimated using figures for average light-duty fuel efficiency from the Energy Information Administration or EPA, and standard factors of GHG emissions per gallon of fuel.

Some recent studies have used a simplified approach to calculate displaced travel. Assuming that every trip made on transit would be taken by car if transit were not available, these studies have applied national ratios of average vehicle occupancy to calculate the number of car trips displaced. This approach ignores the possibilities of walking, biking, or not taking a trip as alternatives to transit (*16,21*).

Analyses of the total mode shift provided by a transit agency or agencies typically can use empirical data on PMT as reported in the National Transit Database (NTD). Analyses of the benefits of specific lines and services require more detailed data. For large projects, displacement of VMT is often analyzed as part of ridership projections or environmental analysis. For smaller projects, sketch planning techniques may be more appropriate.

The Region of Waterloo, which provides transit services in Waterloo, Ontario (in the greater Toronto region), recently estimated the impact of a new bus line on GHG emissions. The Region of Waterloo used a survey of riders and passenger counts to estimate the mode shift effect of the new service. The bus line, termed the iXpress, is a BRT system that replaced a conventional bus system beginning in September 2005. The iXpress service was implemented in conjunction with transit signal priority measures, a web-based trip planner, an automatic passenger counting (APC) system, an AVLC system, community-based marketing initiatives, and inter-modal integration measures. The APC and AVLC systems will be used specifically to monitor ridership and to optimize routes and schedules in the future. The iXpress route extends 35 km (22 mi) and serves 13 stations. The iXpress' better quality service, faster travel times, and improved connections for pedestrians and bicyclists all contributed to increasing ridership on the route.

The Region of Waterloo, in partnership with the University of Waterloo, estimated the impact of the iXpress service on mode shift by recording the daily passenger boardings on the service and surveying passengers to determine how they made their trips before iXpress became available. Results of the survey are presented in Figure 16. Assuming that all auto trips are made by SOVs, we can estimate from these data a mode shift factor of 0.136 for the iXpress. With the benefit of the detailed individual survey responses, the transit agency conducted a slightly more complex analysis than recommended by APTA's methodology. The analysis used individual trip lengths by nontransit mode to calculate displaced emissions, rather than using an average length for all nontransit trips. This technique requires matched data on alternative mode and length of trip for each rider.

Based on this analysis, the transit agency estimated that the iXpress service eliminates 1.5 million km (932,000 mi) of auto travel annually, and thereby displaces 500 metric tons of GHG emissions through travel mode shift. The net impact of the iXpress, accounting for an increase in emissions of transit vehicles from the former conventional bus service to the BRT service, is a reduction of 450 metric tons of GHG emissions annually.

Although empirical data can be used to estimate emissions displaced by existing transit service, analyzing proposed improvements requires the use of ridership forecasts. At the time of the analysis, the Region of Waterloo had not fully implemented all technology measures on the iXpress. Based on projected increases in ridership, the transit agency expects that the mode shift effect of the service will rise to 750 metric tons of GHGs reduced annually 1 year after full implementation of all technologies (*51*).

CONGESTION MITIGATION

Transit agencies can use several different techniques to estimate the additional GHG emissions reduced by their service through mitigation of congestion. Most analyses rely on data from the TTI's annual *Urban Mobility Report*, which provides congestion data for 85 metropolitan areas in the United States (*9*). The *Urban Mobility Report* includes an estimate for each urban area of the amount of gasoline saved by transit's reduction in congestion on roadways.

APTA's methodology offers three approaches to calculating the benefits of reduced congestion:

- *Applying a mode shift factor directly to data reported in the TTI Urban Mobility Report*—This approach is the simplest. It requires only that the transit agencies correct the mode shift factor that TTI uses to calculate the transit congestion reduction benefit (0.8). Agencies should use mode shift factors specific to their regions.
- *Extrapolating from data in the Urban Mobility Report*—This is a more sophisticated estimation technique requiring the application of basic statistical modeling to a time-series of data in the Urban Mobility Report.
- *Applying regional travel demand models*—With this approach, a regional travel demand model is run assuming no transit service, and the increase in vehicle hours of delay and/or fuel consumed in congestion is measured. As with the modeling approach for travel mode shift, the results of this approach depend on the sophistication of the model, and substantial resources may be required to run the model.

The recent CALPIRG study used TTI's figures for fuel savings without adjusting for regional mode shift factors. That study produced estimates of GHG emissions reduced by individual transit agencies across the country. Where a city had more than one transit agency, the benefits of reduced congestion were divided among agencies using each agency's share of regional PMT (*16*). Benefits might also be divided using the share of regional passenger trips. (CALPIRG's results for individual transit agencies are provided in Appendix C.) Both the ICF and SAIC studies, which only calculated

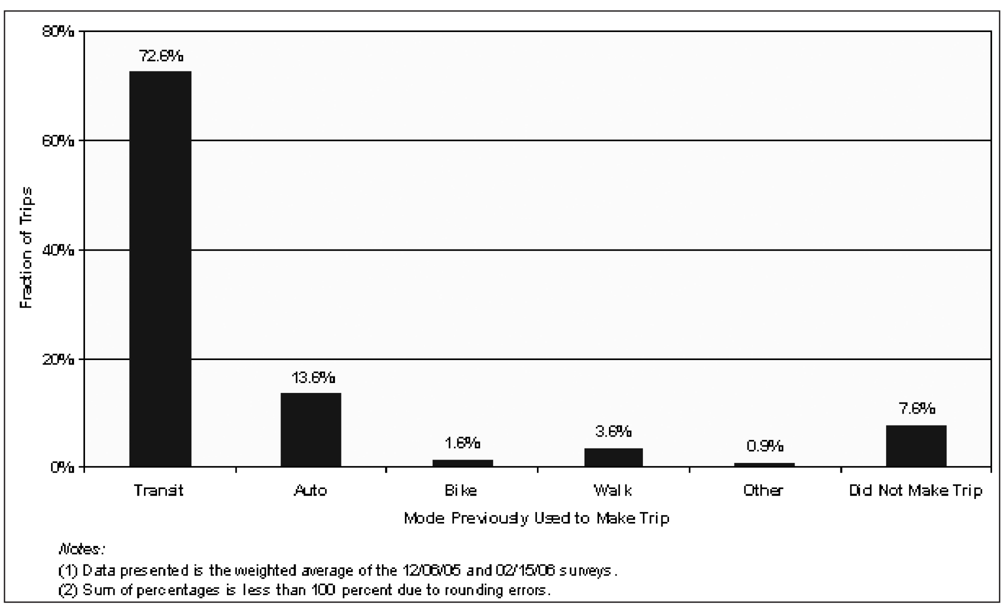

FIGURE 16 iXpress rider survey results—Mode used prior to availability of iXpress. (*Source*: Hellinga and Cicuttin, "Impacts of New Express Bus Service in Waterloo Region," submitted for the Transportation Association of Canada Annual Conference, Session, Integrating Transit Service into Communities, Saskatoon, Saskatchewan, Oct. 14–17, 2007, p. 16).

aggregate impacts of all transit in the United States, also used TTI's figures for fuel savings without modification.

COMPACT DEVELOPMENT

Several methods have been used to quantify the impact of transit on GHG emissions through compact development, but none have yet been widely accepted. The most common way to account for the effect of transit on compact development is through the use of a leverage factor, also known as a land use multiplier. The leverage factor accounts for the indirect benefit that transit provides to those people who do not travel on transit, but whose walking, biking, and driving trips are made shorter by the influence of transit on land use. To account for this indirect benefit, a leverage factor is used to scale up the emissions reduced by direct mode shift of trips to transit.

Leverage factors can be estimated for specific urban regions, for specific transit modes, and for individual transit services. Estimating unique leverage factors is often a complex and data-intensive exercise. Therefore, many analyses use average leverage factors drawn from the literature. A recent CALPIRG study used individual leverage factors for light-rail and heavy-rail transit (factor of 2), commuter rail (factor of 0.4), and bus and other transit (factor of 0). In this case, a leverage factor of 2 means that each passenger mile traveled on light or heavy rail reduces automobile VMT by 2 solely through the indirect effect of transit on land use (*16*). To be conservative, CALPIRG's study assumed that only rail transit had an effect on land use patterns. CALPIRG's leverage factors were based on assumptions drawn from two previous studies (*11,52*). Empirical studies have found, in different urban areas and for different transit corridors, leverage factors between 1.4 and 9 (*4*).

Another recent study used structural equations modeling (SEM), a sophisticated statistical technique, to quantify the impact of transit on GHG emissions through compact development. That study found that, nationwide, the compact development impacts of transit reduce GHG emissions by 29.9 $MMtCO_2$ per year, or as much as all emissions from all transportation in the state of Colorado (*8*) (see Table 2). The leverage factor calculated by the study was 1.9 (*10*).

APTA's methodology considers SEM to be the most robust means to calculate a leverage factor, because it isolates only the effects of transit on development patterns. Leverage factors calculated through other means tend to capture characteristics of land use that are correlated with but not necessarily induced by transit. Transit infrastructure is sometimes integrated into preexisting compact development areas. SEM does not credit transit with the effects of preexisting land use patterns on travel habits.

The preferred method to calculate the leverage factor for a specific region is to conduct an SEM study specific to that region, using a household travel survey specific to the region. NYMTA is currently conducting such a study to best quantify the unique relationship between transit and land use in the New York metropolitan region. This type of study requires a significant effort. An alternative method, avoiding a unique SEM study, uses the default national multiplier of 1.9 calculated by the ICF study. This figure should be viewed as a placeholder, because land use patterns and transit service vary substantially from region to region. APTA is currently developing more detailed guidelines on how to evaluate the impact of transit on emissions through compact development. The guidelines will provide instruction in conducting a tailored regional study, including required resources and statistical techniques (*50*).

Leverage factors can be applied to mode shift effects calculated for existing services or to mode shift effects projected for specific strategies, although transit agencies should take care in interpreting the latter. By using a leverage factor, transit agencies take credit for land use patterns that have co-evolved with transit over many decades. Any new transit strategies would likewise take decades to realize their full effects on land use. A leverage factor therefore should be treated as a long-term benefit of any strategies to improve or expand transit. For TOD strategies, which directly affect compact development patterns, the benefits of land use could be calculated more easily.

Some regional agencies have conducted advanced modeling of how GHG emissions from transportation would change under various scenarios for development of land use and transportation systems. The exercise is known as land use–transportation scenario planning. Types of scenarios evaluated typically include compact development and expansion of transit. The Sacramento Council of Governments conducted such a study in 2004, using a sophisticated software package, to establish a preferred scenario of growth for the region. Compared with a base case scenario in 2050, Sacramento's Preferred Blueprint Scenario substantially increases the percentage of new jobs and housing near transit, reduces the number of trips taken by car by 10%, and reduces per capita CO_2 emissions by 14% (*53*). A 2005 study reviewed the results of this exercise and similar exercises in other regions in the United States. The study found that median impact on VMT for alternative scenarios was a 2% to 3% reduction below base case scenarios (*54*).

Analyses of land use–transportation scenarios are substantially more complex than the calculations described in APTA's methodology. In addition, there is no existing methodology to isolate the benefits of transit from those of land use planning within such a study. Nevertheless, such exercises can provide robust analyses of the combined impacts of transit expansion and land use measures on transportation GHG emissions.

EMISSIONS FROM AGENCY OPERATIONS

Emissions from agency operations, including emissions from transit vehicles, facilities, and construction and maintenance activities, are a standard component of emissions inventories for transit agencies. In most cases, estimation of these emissions simply requires data on the use of fuel or electricity, typically available from agencies' records or from the NTD. Standard factors of GHG emissions are applied to these data to calculate GHG emissions.

The APTA methodology provides guidance on estimating the following:

- Direct emissions from stationary combustion (e.g., on-site furnaces)
- Direct emissions from mobile combustion
- Indirect emissions from electricity use
- Other indirect emissions (e.g., steam purchases)
- Fugitive emissions (e.g., refrigerant leaks)
- Embodied emissions from construction materials.

For a quick snapshot of an individual transit fleet's GHG emissions, agencies can visit www.travelmatters.org. The online transit calculator provides instant estimates for most agencies, based on 2002 NTD data.

Once baseline emissions from any source are calculated, agencies can estimate the impact of specific strategies that reduce emissions. Of those strategies that reduce emissions from agency operations, alternative fuel and vehicle technology strategies have been analyzed most extensively. Changes in fuel or vehicle technologies produce measurable changes in GHG emissions on a per mile basis. Simple reduction factors, such as those provided in Table 7, can be applied to the target vehicle population to estimate emission reductions. The Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation model, from which the factors in that table are drawn, can be used to calculate emission reduction factors for additional fuel types and fuel pathways. Emissions can be calculated on a life-cycle basis or on a tailpipe basis only.

A recent study commissioned by the FTA examined a hypothetical case in which the proportion of alternative fuel buses was increased to 15% of the entire transit bus fleet by 2009. The study examined changes in emissions from this scenario on a tailpipe emissions basis only. Results are provided in Table 12. The study found that diesel hybrid technologies would be the most effective by far to reduce tailpipe CO_2 emissions from buses (*55*).

TABLE 12

IMPACT OF INCREASING ALTERNATIVE FUELS AND TECHNOLOGIES TO 15% OF THE TRANSIT FLEET IN 2009

Alternative Fuel	CO_2 tons	Fuel Consumed Thousands of Gallons
Clean Diesel	35,251	2,664
CNG	−220,758	2,154
Diesel Hybrid	−491,352	−50,658
Gasoline Hybrid	−74,114	2,833
Biodiesel (B20)[a]	25,087	3,876

Change relative to 2009 baseline.

[a] Implemented in the older diesel buses of the fleet.

Source: Wayne, W.S., *Environmental Benefits of Alternative Fuels and Advanced Technology in Transit*, Federal Transit Administration, 2007 (55).

Another study sponsored by FTA examined the GHG emissions performance of various bus propulsion technologies over a 12-year lifespan. The study assumes that buses were purchased in 2007. In this case, the study did use life-cycle (well to wheels) emission factors. Figure 17 provides the results of the study. The study again shows diesel hybrids as the lowest emitting type of bus on a CO_2 per mile basis. CO_2 emissions per mile tend to increase in future years, presumably because fuel efficiency declines as the vehicles age.

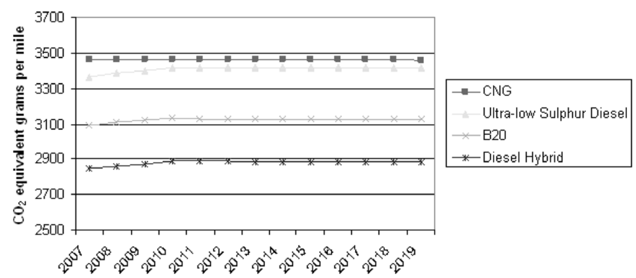

FIGURE 17 Life-cycle GHG emissions from various propulsion technologies (*Source*: Clark, et al., *Transit Bus Life Cycle Cost and Year 2007 Emissions Estimation*, Federal Transit Administration, U.S. Department of Transportation, 2007, p. 34).

A life-cycle emissions analysis of transit can account for all emissions from the transit system, including emissions from building the highway or rail system, manufacturing the vehicles, maintaining the infrastructure and vehicles, producing and using the fuel, and eventually disposing of the vehicles and infrastructure (*3*). Comparing the same life-cycle components for SOVs allows for a full life-cycle evaluation of the benefits of shifting auto-based transportation to bus and rail transportation.

A study from the University of California, Berkeley, compared the actual life-cycle emissions of four rail transit systems with average emissions from buses and SOVs. The rail systems analyzed were San Francisco's BART (heavy rail), California's commuter rail system Caltrain (heavy rail) San Francisco Municipal Railway (Muni) (light rail), and Boston's Green Line (light rail).

> The researchers found that including full life cycle greenhouse gas emissions increased estimates by as much as 70% for autos, 40% for buses, 150% for light rail, and 120% for heavy rail. While including emissions from construction of infrastructure has a larger impact on rail transit than on automobiles, the results still show significant emissions savings from average occupancy rail and bus transit over average occupancy sedans, SUVs, and pickups.

Figure 18 charts the results of the analysis.

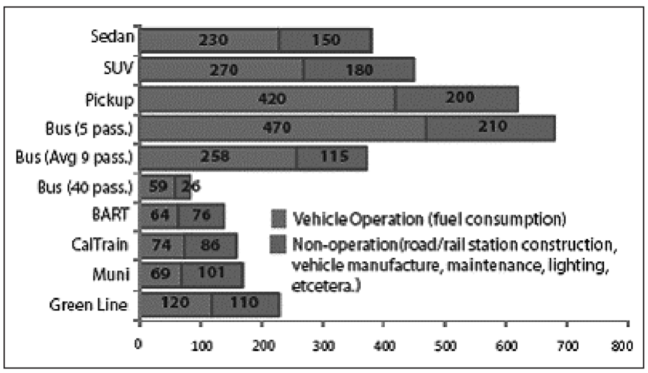

FIGURE 18 Life-cycle analysis of GHG emissions from rail systems: grams CO_2e per PMT (*Source*: Chester, *Life-cycle Environmental Inventory of Passenger Transportation in the United States*, Institute of Transportation Studies, Dissertations, University of California, Berkeley, 2008. Chart taken from Hodges, *Public Transportation's Role in Responding to Climate Change*, Federal Transit Administration, U.S. Department of Transportation, Jan. 2009).

Further research could simplify Chester's aggregate results for transit agencies to use in calculating their own life-cycle GHG emissions benefits. For example, life-cycle emissions multipliers could be developed for each transportation mode. At present, transit agencies have only applied life-cycle emissions analysis to transit fuels.

For other transit emission reduction strategies, analyses are less readily available. To quantify the impact of most of these strategies, transit agencies need to measure or estimate a strategy's impact on the use of fuel, energy, or materials. FTA's forthcoming Transit Greenhouse Gas Emissions Management Compendium should provide some analysis of the emissions reductions possible from such strategies.

ANALYSES CONDUCTED BY SURVEY RESPONDENTS

Many transit agencies surveyed have conducted or are conducting at least a partial analysis of the impacts of their services and operations on GHG emissions. Agencies are estimating both emissions displaced by transit and emissions produced by transit. Of those agencies not estimating GHG emissions displaced by transit, some are still estimating a closely related impact. Because CO_2 emissions are directly proportional to fuel use and are very closely correlated with VMT, agencies were asked about their efforts to analyze impacts on fuel and VMT as well. Nearly two-thirds of respondents said that they are estimating or have estimated the displacement effect (GHG emissions, fuel use, or VMT displaced) of their existing service or planned service improvements. Nearly half of respondents said that they are estimating or have estimated GHG emissions produced by their existing operations or the impacts of strategies on those emissions.

Agencies were asked specifically whether they are estimating or have estimated the displacement effect of their existing service offering. Table 13 summarizes the survey responses. Nearly half of all agencies surveyed have analyzed or are analyzing the displacement effect of their existing service. Fewer agencies are analyzing the specific impacts via compact development or reduction of congestion.

TABLE 13
AGENCIES ANALYZING DISPLACEMENT EFFECT OF EXISTING SERVICE (% of 41 respondents)

Analysis	
Displacement effect on VMT, fuel use, or GHG emissions from private autos	44%
Compact development effect	34%
Congestion mitigation effect	32%

Agencies were also asked whether they are analyzing the impact of specific strategies on displaced emissions. More than one-third of agencies surveyed are analyzing specific strategies. Table 14 shows analyses that agencies have conducted or are conducting. The most commonly analyzed strategies are those that transit agencies tend to analyze for conventional route planning purposes, including new service types, expanded route coverage, and increased service frequency. All strategies are analyzed by at least one agency. GHG analyses are in all cases less common than analyses of VMT or fuel impacts. In some cases, partner agencies may perform the analyses. Metro, the MPO for Portland, Oregon, is performing most of the analyses of strategies for TriMet as part of the update to Metro's Regional Transportation Plan.

Agencies were asked whether they are analyzing or have analyzed the impact of any strategies on their own emissions. About one-quarter of all respondents are analyzing some strategies. Table 15 shows the specific analyses conducted. All types of strategies, except changes to construction equipment and materials, are analyzed. Again, agencies more commonly analyze the fuel or energy impact of strategies than the GHG impact of strategies.

TABLE 14
AGENCIES ANALYZING DISPLACEMENT EFFECTS OF TRANSIT STRATEGIES (% of 41 respondents)

Strategy Types	VMT	Fuel	GHG	Any Analysis
Expanded route coverage	24%	15%	15%	27%
Increased service frequency	24%	12%	15%	27%
Increased hours of operation	15%	5%	7%	17%
New service types (e.g., BRT or LRT)	27%	17%	22%	32%
Transit marketing campaigns	12%	7%	5%	17%
Provision of transit information	7%	2%	2%	12%
Improved transit shelters and station stops	5%	0%	2%	7%
Improved transit access for bicycles and pedestrians	17%	10%	15%	22%
Improved transit access for the disabled and elderly	10%	2%	5%	12%
Improved vehicle comfort	2%	0%	0%	2%
Service improvements; e.g., timed transfers, reduced travel times, improved modal integration	20%	7%	10%	24%
Changes in fare structures or payment methods	10%	2%	2%	10%
Safety improvements	7%	0%	0%	7%
Optimization of existing routes and services	22%	12%	15%	24%
Other strategies	2%	2%	2%	5%
Any analyses				39% (16 agencies)

TABLE 15
AGENCIES ANALYZING EFFECTS OF STRATEGIES ON EMISSIONS FROM AGENCY OPERATIONS (% of 41 respondents)

Strategy Types	Fuel/Energy Use	GHF	Any Analysis
Expansion of transit service	20%	12%	20%
Changes in transit vehicle fleets and/or fuel mix	17%	15%	17%
Energy efficiency measures for office buildings	15%	7%	15%
Energy efficiency measures for maintenance yards	12%	7%	12%
Changes to construction equipment and/or fuel mix	0%	0%	0%
Changes to construction materials	0%	0%	0%
Other strategies	0%	0%	0%
Any strategies			22% (9 agencies)

In conducting analyses of GHG emissions listed in Tables 13–15, transit agencies used several different guidance documents. APTA's methodology was the most commonly cited guidance document. Nearly half of agencies surveyed said that they are aware of APTA's guidance, and many said that they are using or planning to use the guidance. Other sources cited included climate action plans and guidance from Washington State.

Agencies were asked what particular challenges they face in analyzing the impacts of their services on GHG emissions, and what would help to address those challenges. Agencies cited a number of challenges related to calculation methodologies and tools. Calculation of compact development and congestion impacts is particularly difficult for some agencies. Individual comments from agencies included the following:

- "Hard to quantify congestion and land use effects; thus, transit's emissions reduction potential is likely underestimated."
- "It is difficult to estimate GHG reductions resulting from transit oriented land use. Much easier to examine our own fleet and do estimates based on our own data. However, our fleet impact is small when considering the significant changes needed to reduce our region's carbon footprint."
- "The capacity to link travel demand forecasts to GHG emissions is just emerging in our region and is still struggling to account for multiple modes. Getting

good data from our MPO in this regard will help out enormously. Good sketch planning tools for various development scenarios would be very helpful. Isolating the ridership impact of various strategies for the purposes of associating emission reductions with them has proven difficult. Accounting for construction-related emissions (mobile and embodied) across life cycle is quite an in-depth analysis…We haven't been able to move beyond simple default values…due to resource constraints. A tool that would enable some level of tailoring for specific inputs would be very helpful."

A few other agencies mentioned the need for new analysis tools and guidance:

- "We used FHWA and FTA averages for occupancy and average fuel efficiency when calculating the emissions avoided. A standard formula for calculating this would be helpful, as we could ensure we are using the same figures as other agencies. A transit specific carbon calculator would be a helpful tool."
- "We will have to look at the APTA guidance to see how . . . [our agency] compares to other agencies. Compilations of information pertaining to different engine manufacturers and engine types would be beneficial. GHG impacts on typical items such as the new green tip fluorescent tubes and other common items would be beneficial."
- "An electronic calculator like a 'Turbotax' program to input NTD data to complete the calculations for a carbon footprint would be useful. An option to use actual bus emissions instead of factors would be useful to account for replacement of old buses."

A few agencies have had difficulty collecting the data required for detailed GHG analyses. Comments included the following:

- "The greatest challenges are those of education and data collection. The operational information we collect is not all that is needed for GHG impacts. Getting the organization to collect that additional information, especially during times of fiscal constraint, is very difficult."
- "Boundary issues are important (whose emissions are these?). Data issues for older information have been complex. NTD data is only a part of our total emissions; NRV [nonrevenue vehicles] for example not reported. Breadth of services requires data from many sources. Calculating impact on regional emissions difficult."

Some agencies have insufficient resources to conduct detailed analyses. Individual comments included the following:

- "We have completed our GHG emissions inventory for CY2007, but given current budget situation, we are not completing the inventory for CY2008. Funding is an issue. We've done some work on comparing cost-effectiveness in various actions, but more information would be helpful. A sample Climate Action Plan would also be helpful."
- "We have only analyzed GHG impacts at a very gross level to date. Tools that do not require a lot of staff time or data gathering would be beneficial."

Finally, some agencies expressed challenges related to communication:

- "[Challenges include] . . . relating to stakeholders the inverse relationship between transit increase and VMT decrease; agency coordination."
- "Our emissions from our fleet are the largest contributor to GHG emissions. This can become a public perception issue."

Other comments included the following:

- "Establishing the base-line year [is a challenge]."
- "Methodologies should be based on real testing of vehicles as opposed to just dynamometers. Include life-cycle cost. Develop feasible cost-effectiveness range for all projects."
- "Newness of issue [is a challenge]. Need to get everyone involved when there is so much other necessary work to be done. Dire budgets and recession."

Research on the best techniques to evaluate transit's impact on GHG emissions is ongoing. The Florida DOT has contracted Florida State University to pilot APTA's guidance on a sample of transit agencies in Florida. The research has calculated emissions reductions from mode shift and congestion reduction from each agency. The researchers are still considering the appropriate means to evaluate emissions reduced through changes in land use. The project will calculate operational emissions from transit in a future phase (Melanie Simmons, Florida State University, personal communication, March 2009).

The Florida DOT is also sponsoring the development of a toolkit for a carbon footprint that integrates transit. The research will develop a framework for analyzing GHG emissions within existing planning processes, including processes managed by MPOs, state DOTs, and local governments. The tool is not intended for use by transit agencies specifically, but it is expected to highlight the benefits of transit in multimodal transportation planning (Sarah Hendricks, Florida State University, personal communication, March 2009).

EMISSIONS INVENTORIES AND REPORTING

Emissions from agency operations are the core component of GHG emission inventories for transit agencies. An emissions inventory is a detailed account of emissions attributable to an agency, subdivided by source category. Standard definitions of responsibility for emissions are emerging as part of GHG reporting schemes, such as The Climate Registry, a nonprofit emissions reporting agency, and the Chicago Climate Exchange, a voluntary program for trading of emissions credits.

The APTA methodology is intended to guide transit agencies in preparing emissions inventories for submission to The Climate Registry. The Climate Registry uses conventions developed by the World Resources Institute to divide emissions into three scopes:

- *Scope 1: Direct Emissions*—For transit agencies, direct emissions include anything combusted or emitted on the agency's premises or in the agency's vehicles.
- *Scope 2: Indirect Emissions*—Emissions from purchased electricity, heating, cooling, and steam.
- *Scope 3: Optional*—For transit agencies, this scope includes
  - displaced emissions from mode shift to transit, congestion relief, and the land use multiplier;
  - emissions from transit access trips (e.g., to rail stations or park-and-ride facilities);
  - emissions from employee commuting and business travel;
  - life-cycle emissions from vehicle manufacture and disposal;
  - upstream (well-to-tank) emissions from fuel extraction, refining, and transportation; and
  - emissions from waste disposal.

The Climate Registry requires agencies to report only Scope 1 and 2 emissions. Reporting emissions displaced by transit, which fall under Scope 3, is entirely optional. APTA's methodology strongly recommends that transit agencies reporting their emissions to The Climate Registry include Scope 3 emissions to provide a full picture of transit's GHG impacts. Transit agencies preparing detailed emissions inventories should see APTA's guidance document for further direction on how to categorize and estimate the agency's GHG emissions impacts.

Some transit agencies have already compiled emissions inventories, either for internal use or for reporting to The Climate Registry or other organizations. More than one-third of agencies surveyed have estimated or are estimating baseline or historical GHG emissions produced by their agency. Of those agencies, all have included transit vehicle emissions in their estimates. Other components of agencies' emissions are included less frequently (see Table 16 for details). One agency, Sound Transit, reported that they have estimated emissions associated with employee commuting and air travel, and emissions from the nonrevenue fleet. Agencies reported using guidance from the California Climate Action Registry, APTA, The Climate Registry, the Chicago Climate Exchange, and the Sacramento Air Quality Management District to estimate their emissions.

TABLE 16
AGENCIES ESTIMATING OPERATIONAL GHG EMISSIONS
(% of 41 respondents)

Included Emissions	Percent
Transit vehicle emissions	41
Emissions from office buildings	27
Emissions from maintenance yards	34
Construction equipment emissions	7
Emissions associated with production or transportation of materials (embodied emissions)	2
Other emissions	2
Any inventory component	41 (17 agencies)

Eight agencies surveyed indicated that they have reported or are planning to report their GHG emissions to a carbon registry. Agencies are reporting to the California Climate Action Registry, the Chicago Climate Exchange, and The Climate Registry. The San Jose Valley Transportation Authority reports its emissions to a local group called Sustainable Silicon Valley.

Some within the transit industry are concerned about accounting conventions in emissions inventories for transit agencies. The focus to date among carbon registries has been on emissions from agency operations, with little attention paid to emissions that agencies displace. This focus can be challenging for agencies. For example, the Chicago Climate Exchange currently requires members to show a net 6% reduction of base 1998–2001 carbon emissions by 2010. Displaced emissions are not considered in the calculation. This requirement would be difficult for agencies to meet if they are seeking to expand service. The focus on emissions from operations can be challenging to agencies in dealing with public perception and policy makers locally, if agencies are seen as emitters of GHGs and their benefits in displacing GHG emissions are not fully recognized.

Agencies are responding to these challenges both passively and proactively. Some agencies are adopting a wait-and-see approach before joining any carbon registries, because they would like a formal method of accounting for displaced emissions before joining. Other agencies are considering joining the Chicago Climate Exchange to possibly amend the rules of the organization to account for displaced emissions (*3*). APTA's methodology, which focuses on reporting to The Climate Registry, should advance standard procedures for calculating displaced emissions.

COST ANALYSES

The cost of strategies that reduce GHG emissions is a key factor for agencies deciding which strategies to pursue. Transit agencies are heavily constrained by their annual budgets. Strategies that can reduce emissions at relatively low cost or can even save money are of particular interest. Cost analyses compare the fiscal impact of various strategies and aid in decision making.

Two general types of cost analysis applied to transit are cost-effectiveness and cost-benefit analysis (CBA). Cost-effectiveness measures the impact of a strategy on GHG emissions in dollars per ton reduced ($/ton). A highly cost-effective strategy has a low $/ton value; for example, a strategy that costs $50/ton can reduce twice the GHG emissions for the same dollar amount as a strategy that costs $100/ton. Cost-effectiveness for some strategies also can be expressed as $/VMT reduced. Although analyses of cost-effectiveness typically consider only monetary cost and emissions impact, cost-benefit analyses tend to be much broader. CBA compares multiple impacts of strategies by converting each impact to terms of dollars, and in doing so can account for other environmental impacts of transit, such as reduced emissions of criteria pollutants, and societal impacts such as time saved and improved safety. CBA is more appropriate for evaluating transit strategies across multiple objectives, whereas cost-effectiveness is a simpler and more common framework for evaluating just the impact of strategies on GHG emissions, relative to cost.

Although existing research on cost-effectiveness of strategies provides few general conclusions, a few strategies stand out for their fiscal impacts:

- *Strategies that generally save money for agencies and also reduce GHG emissions.* Strategies that reduce the use of electricity and fuel through either operational changes or relatively inexpensive upgrades to facilities and equipment typically save money in the long term. Switching to high-efficiency lighting is one example. New lighting fixtures typically pay for themselves in energy savings within a relatively short period. Using recycled materials in construction also can save money for agencies. For example, TriMet saved millions of dollars by using recycled materials in the construction of a new light-rail line (see Strategies to Reduce Emissions from Construction and Maintenance in chapter four). These strategies produce cost savings for each ton of emissions reduced.
- *Strategies that require large outlays of capital and/or increases in operating costs.* Strategies that expand transit service are often among the most expensive because of large capital and operating costs. Expanding the coverage of fixed-route services can require millions or even billions of dollars per mile. Purchasing new vehicles is also costly. Even operating existing vehicles for longer hours increases operating costs for fuel and wages; very few transit services can pay these costs using fares alone. Both route expansions and increases in service frequency can cost upwards of several thousand dollars per ton of GHGs reduced.

Various factors determine the cost-effectiveness of specific strategies:

- Strategies that increase vehicle passenger loads can be relatively inexpensive, because they make use of existing transit capacity. Marketing campaigns and minor improvements to vehicles, stops, and stations may be relatively inexpensive.
- Strategies that promote compact development may require additional staff effort in planning and development functions, but typically do not require major capital outlays by transit agencies.
- Use of alternative fuels may save money if the alternative fuel of choice is locally available at a lower price than conventional fuels. For example, King County Metro has seen the cost-effectiveness of biodiesel fluctuate between more than $100/ton and less than $0/ton (cost savings) as fuel prices have changed. However, if new alternative fuel vehicles must be purchased at higher cost than conventional vehicles, the net cost of such strategies will be higher. Currently, a hybrid bus costs roughly $500,000 and trolley buses cost around $850,000, whereas a conventional diesel bus costs about $350,000 (*56*).
- The net cost of many strategies that reduce fuel consumption in existing vehicles depends on the cost of new training programs, maintenance programs, and technology upgrades, as well as on the amount of fuel saved.

Cost-effectiveness of individual strategies can vary widely. For example, BRT systems in Los Angeles, California, and Vancouver, British Columbia, are estimated to cost $117 per ton and $3,238 per ton, respectively (*57*). Vanpool services for agricultural workers in Kings County, California, cover their own operating costs with fares and save 413 tons of CO_2 emissions per month. In addition, the Kings County Area Public Transportation Agency estimates that the service produces indirect cost savings, such as savings for riders and businesses in the area, of $59 million per year (*30*).

To analyze the cost-effectiveness of a strategy, agencies must calculate both the cost and the emissions impact of the strategy. The most desirable transit strategy for cost-effectiveness reduces the most emissions for the least money. An expensive strategy may be cost-effective in terms of $/ton if it reduces a large volume of emissions. Depending on the purpose of the analysis, agencies may wish to consider only internal costs and savings to the agency, or may consider costs borne by and savings accrued to other stakeholders and the public as well.

Assigning a cost to GHG emissions allows GHG impacts to be included in a CBA of strategies, in which all impacts of a given strategy are monetized. A CBA analysis including GHG emissions was conducted for conventional diesel, hybrid diesel-electric, and CNG buses used by the New York City Transportation Authority. For each bus technology, the analysis included capital expenditures, operations and maintenance expenditures, and environmental impacts, as well as several smaller categories of costs and benefits. The study used a value of $149/ton of GHG. The analysis was conducted during the period of operation of alternative bus types, when empirical data were available to inform the calculation. Evaluating all cost components of a strategy is generally more difficult before the strategy is implemented (*58*).

While New York's study used a price of $149/ton, any price assigned to GHG emissions currently is largely speculative. Estimated prices may be based on the costs of emission reduction strategies, economic forecasts, or results from fledgling emissions markets. One agency surveyed, New Jersey Transit, has conducted cost analyses assuming that the cost per ton of GHG will fall in the range of $4 to $50 between now and 2020. These analyses will become part of the state's climate action plan.

Although more than a quarter of all agencies surveyed reported that they have estimated or are estimating the cost-effectiveness of strategies in terms of $/VMT or $/ton, very few transit agencies have yet to undertake a comprehensive analysis of cost-effectiveness for a range of GHG reduction strategies. BART is one of the first. In a recently released study, BART compared the cost-effectiveness of measures that are fully within the control of BART (including those related to fares, access, and service) with measures that require coordination with other regional partners for broader land use and transportation changes (including transportation pricing and land use policies). BART's analysis assessed only public sector costs, and not costs to individuals or businesses.

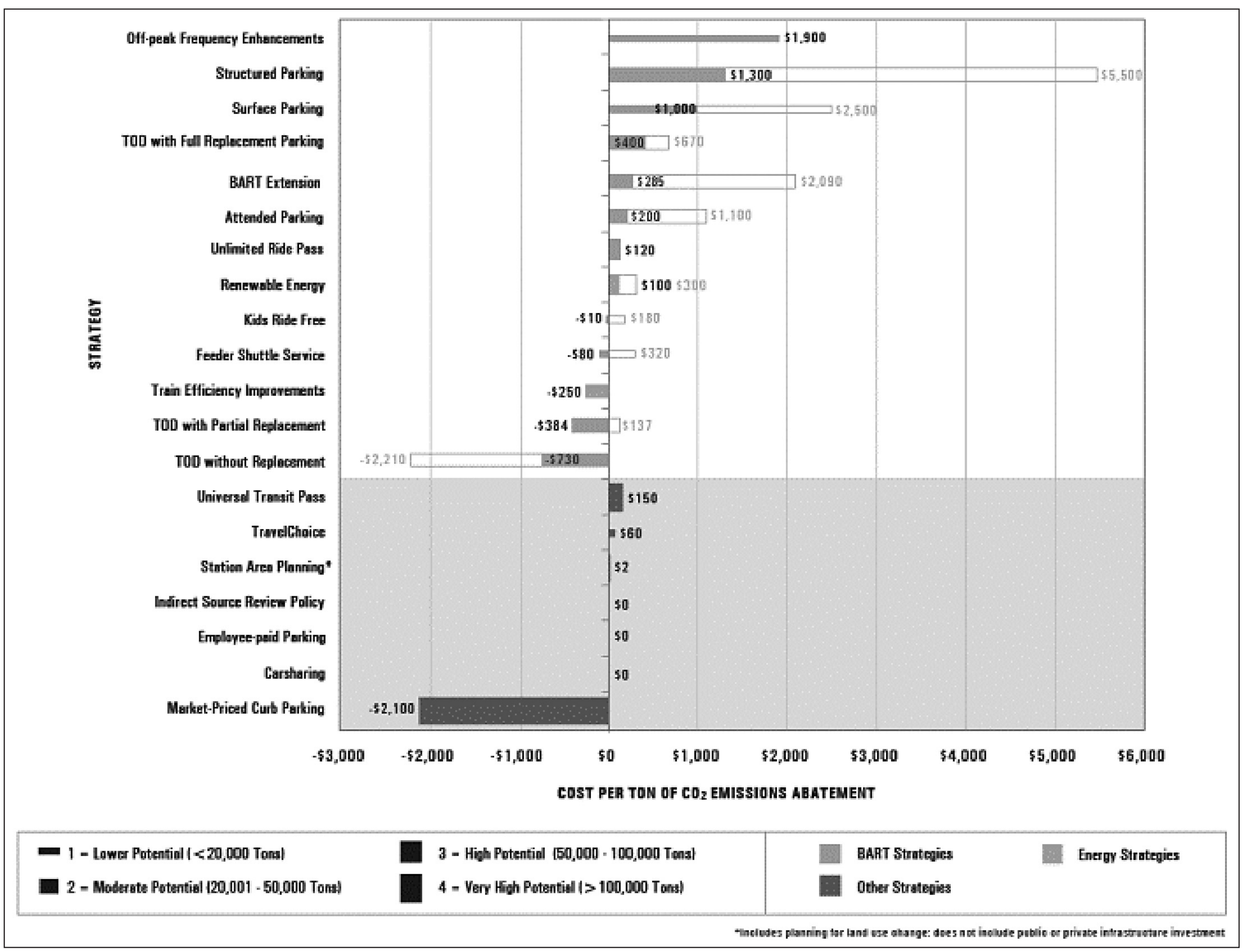

FIGURE 19 Cost-effectiveness of BART strategies (*Source*: Nelson\Nygaard Consulting Associates, *BART Actions to Reduce Greenhouse Gas Emissions: A Cost-Effectiveness Analysis*, San Francisco Bay Area Rapid Transit District, San Francisco, Calif., Nov. 2008, p. 2).

A summary of results from the study is provided in Figure 19. The study found that the least cost-effective strategies for BART are those requiring significant new capital or operations spending, such as new parking facilities, increased service frequency, and system extensions. More cost-effective strategies include fare incentives, marketing, and feeder shuttle service. The study found TOD strategies on BART property to be net generators of revenue for BART, and also to have high potential to reduce GHG emissions (*59*). Analyses were based on empirical results from actual strategies tested or implemented by BART and other transit agencies.

SFMTA also compared the costs of some strategies that reduce GHG emissions in its recently published Climate Action Plan; however, the plan does not provide information on the cost-effectiveness of strategies, in $/ton.

Washington State explored methods to assess the cost-effectiveness of a proposed transit expansion (see Effectiveness of Transit Strategies in chapter four), although no methodology was sanctioned for inclusion in the Climate Action Plan. Cost elements considered included increases in agencies' operating, capital maintenance, and capital expansion costs. Cost savings included a reduction in the variable costs of owning and operating a vehicle (for transit users), reduction in congestion costs (for the traveling public), reduction in parking costs (for transit users), and reductions in vehicle crashes and air pollution costs (for the public).

Although agencies may find cost analyses conducted by other organizations informative, they should take care when applying findings to their own circumstances. Both costs and GHG impacts of strategies can vary substantially based on the specific design and context of strategies. In addition, different analytical scopes and methodologies can produce widely varying results. The results of cost-effectiveness estimates depend heavily on the assumptions used, including factors such as energy prices, scale and aggressiveness of strategies, and the types of costs considered. Cost analyses can account for costs to transit agencies, other government agencies, transit users, businesses, the public, or any subset of these groups. Some strategies may appear relatively cost-effective to reduce a few tons of GHG emissions, but become less cost-effective as they are scaled up. Comparison of cost-effectiveness across different strategies and application of cost-effectiveness results from one context to another require particular caution.

There has not yet been a cost-effectiveness analysis of many transit strategies over a variety of contexts, which could provide some generalizable conclusions across transit agencies. A forthcoming study from the Urban Land Institute, *Moving Cooler*, will include national-level estimates of GHG cost-effectiveness for some broad types of transit strategies, as well as many other transportation GHG reduction strategies.

Ideally, transit agencies would conduct their own cost-effectiveness analyses of GHG reduction strategies. But little guidance is available for agencies desiring to conduct cost-effectiveness evaluations. *TCRP Report 93* does include a suggested methodology to compare the cost-effectiveness of various alternative vehicle technologies to reduce GHG emissions (*6*). In general, estimating the cost-effectiveness of technology-based strategies, for which the scope of cost and cost savings is largely limited to the transit agency and from which there are few co-benefits, is simpler than estimating cost-effectiveness for strategies with broader impacts on transportation systems. Agencies can adapt cost-effectiveness methodologies intended for other air pollutants to estimate $/ton of GHG. Pinellas Suncoast Transit Authority in St. Petersburg, Florida, is planning to adapt methodologies prepared by the California Air Resources Board (CARB) for cost-effectiveness evaluation of criteria pollutants. (CARB's guidance documents are available at http://www.arb.ca.gov/planning/tsaq/mvrfp/mvrfp.htm.) Agencies interested in conducting cost-effectiveness evaluations should see the Victoria Transportation Policy Institute's *Evaluating Public Transit Benefits and Costs: Best Practices Guidebook* (2008) for more background on types and amounts of cost and cost savings (*60*).

Agencies should also keep in mind that GHG cost-effectiveness is a limited metric for evaluation of strategies. Transit service provides many co-benefits—including reducing congestion, reducing emissions of criteria air pollutants, and providing access to jobs and schools for disadvantaged communities—that are not accounted for in terms of $/ton of GHG reduced. Transit provides a relatively high level of co-benefits when compared with other types of transportation GHG reduction strategies. Therefore, $/ton analyses across different modes tend to disadvantage transit. A full CBA is more complicated, but it is better able to account for multiple types of benefits.

CHAPTER SIX

GREENHOUSE GAS POLICIES AND PLANNING

Many transit agencies reduce GHG emissions from transportation through their existing public transportation services. When agencies implement strategies that further reduce GHG emissions, customer service, cost, and existing environmental regulations are often the primary drivers. Targeted planning for GHG reductions is relatively rare at transit agencies. At the same time, many states and even the federal government are moving toward regulation of GHG emissions from transportation and other sectors. A few transit agencies are developing policies and planning procedures for GHG emissions.

STATE AND FEDERAL GREENHOUSE GAS POLICIES

Pressure is now mounting within the federal and state governments for the transportation industry, as well as other industries, to manage and reduce their GHG emissions. In particular, the Obama administration has called for Congress to pass legislation to reduce GHG emissions. Legislation that would affect the transportation industry could come in the form of amendments to the Clean Air Act, reauthorization of federal transportation funding, or a separate piece of legislation devoted to climate change. Congress has already devoted substantial attention in recent years to the possibility of an emissions trading scheme for GHG emissions. Ten bills containing emissions trading provisions were introduced during the 110th Congress; some of these bills included the transportation sector.

Some state governments have established policies requiring a reduction in GHG emissions. Beginning with California's Assembly Bill (AB) 32, passed in 2006, 21 states have adopted targets to reduce GHG emissions. Figure 20 shows states that have adopted targets. Many states have also joined regional multistate GHG emissions trading schemes, including the Western Climate Initiative, the Regional Greenhouse Gas Initiative in the northeast, and the Midwestern Greenhouse Gas Reduction Accord. So far only the Western Climate Initiative plans to include transportation emissions in its trading scheme.

Thirty-six states have developed or are developing comprehensive climate action plans to reduce GHG emissions (*61*). These plans typically propose and analyze the emissions impacts of strategies for the transportation, energy, and agriculture and forestry sectors. Most states have included transit strategies in their climate action plans.

A few states are beginning to implement transportation measures to achieve their GHG reduction goals. California passed landmark Senate Bill (SB) 375 in 2008, which will establish regional targets to reduce GHG emissions from passenger travel for California's 18 MPOs. As part of their long-range transportation planning processes, MPOs will be required to prepare strategies that identify how they will meet these regional targets and to use their transportation funding authority to achieve the targets. MPOs will have to quantify the impacts of strategies to reduce GHG emissions.

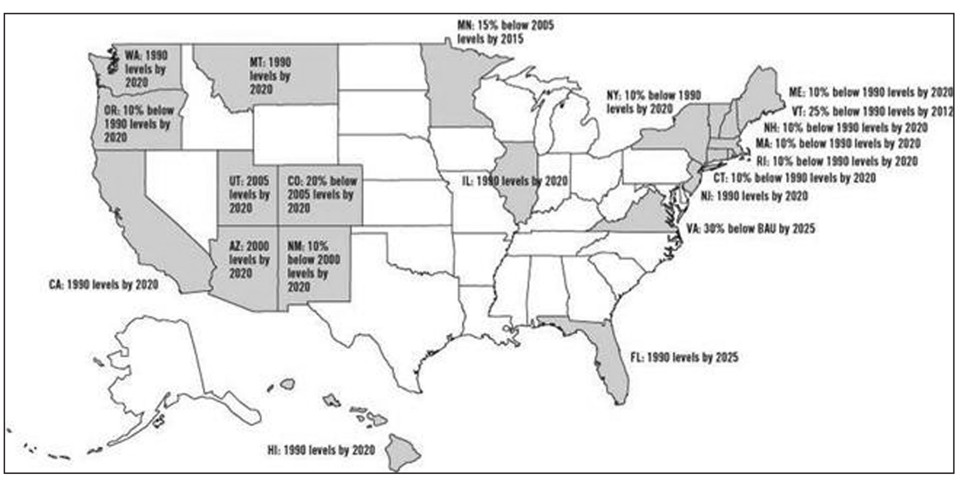

FIGURE 20 States with GHG reduction goals (*Source*: Pew Center on Global Climate Change, "Climate Change 101: State Action," Jan. 2009.)

SB 375 is likely to encourage investment in transit in California's urban regions.

Washington State enacted House Bill (HB) 2815, Climate Action and Green Jobs, in 2008. One provision of the bill requires the Washington State DOT (WSDOT) to adopt goals to reduce statewide VMT. The bill sets the following targets:

- Reduce annual per capita light-duty VMT 18% by 2020
- Reduce annual per capita light-duty VMT 30% by 2035
- Reduce annual per capita light-duty VMT 50% by 2050

The targets are applied to a baseline of 75 billion VMT, roughly the total VMT projected for the state in 2020. In preliminary implementation efforts, WSDOT has established transit strategies as a key element of plans to meet the VMT reduction targets (*62*).

HB 2815 also requires reporting of GHG emissions by any agency that operates an on-road vehicle fleet that emits at least 2,500 metric tons of greenhouse gases annually. This rule will affect most transit agencies in the state. The Washington State Department of Ecology is tasked with issuing a reporting rule; 2010 will be the first year of reporting. The Department of Ecology will use a simplified method of reporting based on fuel usage.

Transit agencies will inevitably be involved in the implementation of VMT and transportation GHG standards, and may receive more funding as a result. Transit agencies have already contributed to the first implementation steps for HB 2815 in Washington. Representatives from King County Metro provided policy input and technical expertise to estimate the amount of VMT and GHG reduction that could be achieved from various transit expansion packages in Washington State. In California, SB 375 likely will cause MPOs to direct more regional transportation funding to transit systems. MPOs will need to quantify the GHG savings from transit, most likely using input from transit agencies.

Agencies were asked whether they are affected by any state, regional, or local policies on GHG emissions. Twenty-five agencies, or nearly two-thirds of respondents, answered yes. Agencies cited policies including state and local GHG reduction targets, state and local climate action plans, and alternative fuel mandates. The balance of responses suggests that most of these agencies are not yet facing specific legal requirements, but that they are anticipating new requirements as legislation is implemented over a period of several years. Specific policies cited include the following:

- California's AB 32 and SB 375
- New Jersey Global Warming Response Act
- Arizona's Executive Order 2006-13
- Oregon's state goals for GHG reduction
- Florida Executive Order 07-127
- WMATA stated that its local jurisdiction has instituted a requirement for LEED certification that affects the agency's design and construction activities.

Transit agencies may benefit from any GHG emissions trading schemes at the national or state levels. Emissions trading schemes allow parties to buy and sell emissions "credits." Entities' eligibility to participate in such a carbon market would depend on the exact design of such a scheme. Some schemes could allow transit agencies, as net reducers of GHG emissions, to generate and sell emissions credits. Sales of emissions credits would be a new source of funding for transit. Sacramento Regional Transportation District, New Jersey Transit, and BART all cited potential revenue from trading schemes as a factor in their efforts to reduce GHG emissions.

POLICY AND PLANNING AT TRANSIT AGENCIES

To date, no significant research has documented transit agencies' experiences with planning for reduced GHG emissions. Most research on transportation planning and GHG emissions has focused on the roles and processes of MPOs and state DOTs, and has largely focused on road-based transportation. While transit agencies are partners in the transportation planning and funding exercises led by these agencies, their roles and their internal processes have received less attention.

The survey asked transit agencies several questions about their experiences planning and implementing strategies to reduce GHG emissions. This section includes responses to those questions. The reader should keep in mind that few agencies have extensive experience with targeted initiatives to reduce GHG emissions. For most transit agencies, GHG emissions are an emerging concern and have been addressed only when they overlap with other priorities, such as reducing costs or reducing emissions of criteria pollutants. The reader should keep in mind that agencies with more robust initiatives to reduce GHG emissions are more likely to respond to the survey. Individual responses reflect the respondents' best understanding of their agencies' activities and policies.

Agencies expressed a high degree of interest in issues related to GHG emissions. When agencies were asked whether they are considering how they can reduce GHG emissions from their own operations or from the transportation sector, 38 of 41 respondents answered yes.

Agencies were asked how and where they considered GHG emissions in decision-making processes. Nearly half said that they consider GHG emissions in long-term or short-term planning, which might include strategic plans and system development plans. Nearly one-quarter said that they consider GHG emissions in planning for specific lines or services, which might include consideration of GHG emissions in studies related to route expansion. One-third of respondents said that they consider GHG emissions only informally. Informal consideration might be as simple as a single staff member recognizing or promoting the GHG benefits of strategies. Only two agencies said that they do not consider GHG emissions at all in decision making. One agency, AC Transit, noted that it is beginning to consider GHG emissions during the planning of capital projects and in leasing agreements for buildings and vehicles.

Some transit agencies have specific policies in place or are developing policies to reduce GHG emissions. Such policies can be important drivers to incorporate GHG emissions in decision making. Agencies were asked whether they had adopted or begun to develop policies to reduce GHG emissions. About one-third of survey respondents answered yes. Agencies cited policies and initiatives, including the following:

- Sustainability policies and programs
- Alternative fuel policies
- Environmental management systems that incorporate GHG policies and reduction strategies
- Climate action plans
- Efforts to comply with state or regional reduction targets
- Joining the APTA Sustainability Pilot Program

A handful of transit agencies are helping to pilot APTA's Sustainability Commitment. Signatories to the Commitment will agree to establish goals to reduce GHG emissions. APTA provides sample text on which transit agencies can base their goals, including goals related to the agency's entire carbon footprint, carbon emissions from agency administration, electricity use, and fuel use in transit vehicles. Sample commitments include the following:

- *Reduce your organization's carbon footprint in terms of emissions per passenger mile by __ percent over baseline by 20__*
- *Reduce overall carbon emissions of administrative function of organization by ___ percent over baseline*
- *Reduce electricity use by ____ percent over baseline*
- *Reduce fuel use per unlinked passenger trip by _____ percent over baseline by 20__*
- *Reduce VMT per capita in your community by __ percent over baseline by 20__* (*63*).

At least one agency surveyed, the Utah Transit Authority, is a signatory to the International Association of Public Transport's Sustainability Charter. The charter commits signatories to fostering environmental protection, social justice, and economic sense. Signatories pledge to measure their progress in reducing GHG emissions and improving energy efficiency (*64*).

Coordination with other transportation stakeholders is likely to be an important element to planning and implementing GHG reduction strategies. Some strategies to reduce emissions require transit agencies to coordinate with other agencies. Compact development strategies and congestion mitigation strategies in particular require cooperation, but other strategies over which transit agencies have more immediate control can benefit from interagency cooperation. In addition, some types of policies over which agencies have no control, such as parking pricing, can have substantial impacts on the ability of transit to reduce GHG emissions.

Agencies were asked whether they had engaged in any discussions with regional stakeholders on climate change issues. Twenty-eight agencies, or more than two-thirds of survey respondents, answered yes. Agencies cited initiatives, including the following:

- Participating in the drafting of city, regional, and state climate action plans and GHG inventories
- Discussing regional transportation plans with MPOs
- Hosting summits for local and regional agencies
- Discussing GHG policies and measurement tools with state, regional, and local governments

Although many efforts that reduce GHG emissions are part of the conventional staffing load at transit agencies, new efforts on GHG emissions, such as policy and strategy development, analysis, and reporting, require significant staff resources. Agencies were asked whether they have specifically designated any staff to address GHG issues. Fourteen agencies, or about one-third of respondents, have designated staff. Agencies were also asked in what departments the designated staff is housed. Agencies cited a wide variety of departments, including departments of planning, environment, technology, development, maintenance, and risk management. Several agencies have spread responsibilities across multiple departments. For example, BART spreads responsibilities across offices of planning, operations, environmental compliance, and system development.

Staffing efforts to reduce GHG emissions are one possible challenge for transit agencies. Agencies may face a number of other challenges in trying to reduce GHG emissions. Agencies were provided a list of potential challenges and asked to rank the challenges they see as most impeding efforts to reduce GHG emissions. Table 17 provides a summary of responses. The largest number of agencies cited lack of funding and lack of staff capacity (in terms of person-hours) within the top three concerns. These concerns are closely related, as additional funding is often required to hire staff to perform new functions related to GHG emissions strategies. Funding is also important for capital and operating budgets needed to maintain and improve transit service. Challenges related to planning functions, such as internal policies and decision-making processes and coordination with other agencies, were cited least frequently among agencies' top concerns.

TABLE 17
CHALLENGES AGENCIES ARE FACING IN REDUCING GHG EMISSIONS (% of 41 respondents)

Challenge	One of Top Three Concerns	Is a Concern
Lack of funding	61%	73%
Lack of staff capacity (person-hours)	51%	63%
Lack of appropriate tools, data, or analysis techniques	29%	68%
Lack of staff know-how	22%	59%
Technical barriers to implementation of emissions reduction strategies	22%	56%
Lack of organizational mandate/policy	20%	63%
Planning mechanisms/procedures do not consider GHG emissions	12%	56%
Difficulty describing the GHG benefits of strategies to stakeholders/decisions makers	10%	59%
Insufficient partnerships with other regional players (e.g., cities, MPOs, and other transit agencies)	5%	56%
Other	5%	7%

Agencies were asked what they would need to overcome the challenges they cited. Not surprisingly, many agencies said they needed more funding, more staff, and more training for staff. Several agencies cited a need for clear, consistent methodologies to calculate GHG emissions produced and displaced by transit agencies. A standard approach would be beneficial, and might help transit agencies get more recognition for the role they play in reducing GHG emissions. The APTA Climate Change Working Group's recommended practice might serve as such a standard approach. One respondent cited the need for an internal policy on GHG emissions to make the issue a bigger priority throughout the organization.

Transit agencies' policies and planning processes related to GHG emissions are likely to be an important factor in reducing GHG emissions in the future. Although transit typically provides a net GHG reduction benefit already, planning efforts that target GHG emissions can increase that benefit. Targeted policy objectives and planning exercises, and coordination with other stakeholders, foster strategies that further reduce GHG emissions. Many transit agencies surveyed showed a substantial interest in developing more robust planning mechanisms that take GHG emissions into account.

San Francisco Municipal Transportation Agency's Climate Action Plan

SFMTA released a draft of its Climate Action Plan in December 2008 (see Figure 21). The plan provides details of the agency's strategies to reduce transportation GHG emissions. Transit strategies include optimizing existing routes and service, providing real-time transit information, implementing transit signal priority, and making fare payment more convenient for customers. The agency has other strategies to reduce its own emissions, including using biodiesel, hybrid-electric, and fuel cell buses; improving energy efficiency in facilities; recycling waste from facilities; and using green construction techniques.

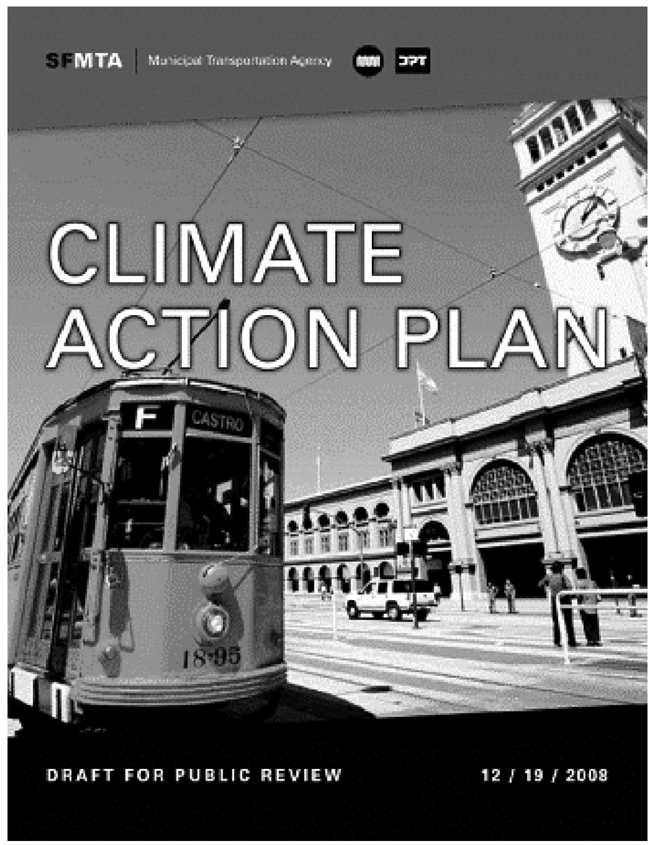

FIGURE 21 SFMTA climate action plan (*Source*: "Climate Action Plan," San Francisco Municipal Transportation Agency San Francisco, Calif., 2009 [Online]. Available: http://www.sfmta.com/cms/rcap/capindx.htm.

SFMTA prepared its Climate Action Plan in the context of several legislative and regulatory requirements. A 2007 municipal referendum called for the transportation sector in San Francisco to reduce GHG emissions by 20%, and required SFMTA to prepare a climate action plan. In addition, the city of San Francisco has called for all city departments, of which SFMTA is one, to reduce carbon emissions levels 20% below

1990 levels by 2012. SFMTA expects to meet the goal for operational emissions. Transit service would need to double, in conjunction with other strategies, for the transportation sector to meet its overall goal. The Climate Action Plan proposes a number of indicators to measure progress toward the established GHG reduction goals. The current draft plan does not include any quantitative analyses of strategies, but discusses the need for quantification (*56*).

New York Metropolitan Transportation Authority's Sustainability Plan

NYMTA, North America's largest mass transit network, recently completed a sustainability planning document entitled *Greening Mass Transit and Metro Regions* (*65*). The agency's Blue Ribbon Commission on Sustainability and the MTA, appointed by the executive director, was charged with developing recommendations for the agency. Energy and Carbon is one key area designated for action. Reducing CO_2 emissions is one of the report's principal concerns.

FIGURE 22 Solar roof, Roosevelt Avenue Station, MTA New York City Transit (*Source*: *Greening Mass Transit & Metro Regions: A Synopsis of the Final Report of the Blue Ribbon Commission on Sustainability and the MTA*, Metropolitan Transportation Authority, State of New York, Feb. 2009).

The report contains more than 100 recommendations, including a recommendation that the agency draw more than 80% of its operating energy from clean, renewable sources by 2050, including solar, wind, and tidal energy. MTA has already more than 300 kW of solar panels at two subway stations and one bus depot (See Figure 22). The report also recommends a major expansion of regional transit access. Two-thirds of the region's new development should be clustered within a quarter-mile to a half-mile of MTA transit access. The agency should reduce GHG emissions per passenger mile by 25% by 2019. Other recommendations include achieving LEED standards for facilities, enhancing recycling initiatives, and preparing for adaptation to the expected effects of climate change. Priorities for legislation and policy at the federal, state, regional, and local levels are also proposed. The report estimates reductions in emissions that can be achieved through some of its recommendations. For example, retrofitting existing rail cars with regenerative braking technology could save 165,000 tons of CO_2 per year. The report recommends that the agency pursue reducing CO_2 emissions as a potential source of revenue and proposes a new metric to assess investment decisions, a sustainable return on investment model, that would include a price for CO_2 (*65*).

CHAPTER SEVEN

CASE STUDIES

This chapter presents three case studies of agencies that are working to reduce GHG emissions:

- BART—San Francisco, California
- LA Metro—Los Angeles, California
- LYNX—Orlando, Florida

SAN FRANCISCO BAY AREA RAPID TRANSIT

BART provides commuter rail service in the metropolitan region of San Francisco and Oakland, California, with a total urban area population of 3.2 million. BART provides 1.4 billion passenger miles of service annually on 209 directional route miles.

BART has begun to consider its role in reducing GHG emissions just in the past two to three years. A representative from BART sits on the APTA Climate Change Standards Working Group. BART is planning and implementing a full range of strategies that can reduce GHG emissions from the regional transportation footprint and from the agency's own operations, although many of these strategies are pursued primarily to improve air quality and accessibility, and reduce costs. BART's current and future strategies include the following:

- *TOD planning*—BART is planning and constructing TOD at several of its rail stations, in partnership with local and regional governments and with other regional transit agencies. BART views this strategy as particularly important to reducing regional GHG emissions.
- *Energy-efficiency measures for rail cars and stations*—A study jointly commissioned by BART and the local electric utility, Pacific Gas & Electric, found that BART could save substantial electricity through measures such as improved regenerative braking and lighting and improvements to heating and air-conditioning systems in rail cars and stations. These measures also would help to reduce GHG emissions.
- *Renewable energy*—BART already draws about two-thirds of its energy from low-GHG hydroelectric plants. The agency is considering expanding its use of clean energy.

BART is one of the first transit agencies in the country to study the cost-effectiveness of a range of options to reduce GHG emissions (see Cost Analyses in chapter five). The study is intended to prepare BART to take advantage of any funding opportunities that may arise for strategies that reduce GHG emissions. BART is actively monitoring legislative and regulatory developments that affect GHG emissions, including California's AB 32 and SB 375. The agency sees a potential to sell credits under an emissions-trading scheme. The information on strategy cost-effectiveness may prepare BART to apply for any grant funds that may become available to reduce GHG emissions.

BART is conducting a separate exercise to estimate its own emissions from operation of service vehicles, facilities, and associated administrative functions. BART intends to incorporate the cost-effectiveness and inventory studies into a comprehensive Climate Action Plan that will inform decision making. BART has not yet conducted a comprehensive assessment of emissions displaced by its service.

BART is also conducting an initiative to publicize the benefits of its service to GHG emissions, as well as other environmental benefits, as part of a marketing drive. BART's internally released "Green Facts" sheet provides information on the impact that an individual can have on GHG emissions by taking BART. It also provides information on some of the strategies that BART is using and planning to reduce its own energy use and GHG emissions. BART has added a carbon calculator to its web-based trip planner (www.bart.gov) and has received positive reactions from users (see Figure 23.BART hopes that publicizing the GHG benefits of its services will improve public opinion of the agency and eventually bring more funding to the agency.

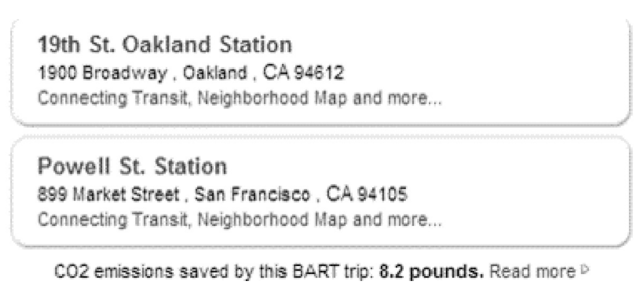

FIGURE 23 BART CO_2 calculator.

BART has adopted several internal policies relevant to GHG emissions. BART's sustainability policy includes a goal to decrease consumption of energy and resources by using sustainable materials in BART facilities. BART's Strategic Plan, adopted in 2008, incorporates a goal to reduce GHG emissions per BART vehicle-mile and a goal to contribute to a reduction in VMT in the San Francisco Bay Area.

LOS ANGELES METRO

LACMTA, or Metro, is the manager of a major transit system for Los Angeles County and is the county's regional transportation planning authority. Public transportation provided by Metro serves the urban areas of Los Angeles, Long Beach, and Santa Ana, California, with a total population of 11.8 million. The agency operates more than 2,000 buses, 32 directional route miles of heavy rail, and 110 directional route miles of light rail. Metro operates the second-largest bus fleet in the nation after NYCMTA. More than 2 billion passenger miles are traveled on Metro service every year.

Metro has launched an agencywide sustainability initiative that incorporates reducing GHG emissions as a principal component. In July 2007, the agency established an Ad-Hoc Sustainability and Climate Change Committee. In 2008, the agency published the Metro Sustainability Implementation Plan (MSIP). That plan recognized the need to centrally organize, identify, measure, and report on strategies to reduce GHG emissions and otherwise improve the agency's sustainability record. The MSIP contains specific deliverables to advance the sustainability agenda.

Metro's board of directors authorized funding for two staff positions to support its sustainability efforts. One staff person will act as a legislative and policy coordinator within Metro's Planning Business Unit, while the second staff person will work in Metro's Construction Business Unit to support the implementation of projects that improve sustainability and reduce GHG emissions. Metro has organized its sustainability efforts into four distinct efforts: (1) Legislative and Policy Coordination, (2) Climate Change and Greenhouse Gas Emissions Reduction, (3) Energy Efficiency and Renewable Energy Efforts, and (4) Environmental Management Systems.

Metro is planning and implementing a full range of strategies that reduce GHG emissions, including strategies to expand service, increase passenger loads, reduce congestion, promote compact development, and reduce emissions from its transit vehicles and other functions. A few of Metro's flagship operations that reduce GHG emissions are its CNG bus fleet, the largest in North America, and its solar energy program. Metro has solar photovoltaic arrays that currently generate 1.85 MW of electricity. Metro has initiated energy-efficiency retrofits in its headquarters and other facilities, has completed construction of a LEED Gold–rated building, and is currently constructing other environmentally friendly buildings. Metro has begun incorporating sustainability design guidelines into transportation projects such as the Metro Orange Line Extension in the San Fernando Valley. The agency has partnered with a number of joint developers to build TOD around its stations.

Metro completed a GHG inventory in December 2008. The inventory accounts for emissions from transit vehicles, office buildings, and maintenance yards, but not emissions displaced by Metro's services. The agency is awaiting further guidance on how emissions displaced can be incorporated into emissions inventories for transit agencies. Metro has chosen not to report its emissions to a registry such as The Climate Registry or the Chicago Climate Exchange until reporting protocols are clarified.

In late spring 2009, Metro completed a baseline sustainability report that analyzes its environmental performance and the economic costs of its core activities. The report includes an update of Metro's GHG emissions inventory, proposes sustainability indicators through which the agency can track progress toward sustainability, and outlines recommendations to further reduce Metro's overall environmental impact.

Metro plans to monitor and provide input to various local, state, and federal organizations developing climate change policies that will affect Metro. Metro is actively considering the impact that existing and future GHG policies—including AB32 and SB375 (California's central GHG emissions regulations), regulations for the California Environmental Quality Act, and forthcoming federal transportation and climate change legislation—will have on the agency.

Metro also acts as a regional facilitator of sustainability efforts. The agency recently hosted its Second Annual Sustainability Summit. The summit brought together cities in and adjacent to Los Angeles County, as well as regional agencies, to discuss sustainability issues including GHG emissions.

In addition to Metro's Sustainability Implementation Plan, the agency has adopted policies, including the following:

- *Energy and Sustainability Policy*—Commits the agency to striving for LEED standards in its buildings and to conducting energy audits.
- *Construction and Demolition Debris Recycling and Reuse Policy*—Commits the agency to pursue recycling of construction waste.
- *Environmental Policy*—Incorporates the intent of the specific sustainability and recycling policies and commits the agency to reducing GHG emissions from its own footprint and from the transportation sector, in addition to other environmental goals.

Metro is working to educate both its employees and the public about the issue of climate change and the impact of Metro's service on GHG emissions. The agency is running an ad campaign to that end. One of the agency's ads is shown in Figure 24. Metro has developed a training program on sustainability awareness and is working with other regional learning institutions to further enhance the number of classes that will deal with the issue of climate change.

FIGURE 24 Metro marketing materials (*Source*: Metro Sustainability Implementation Plan, Los Angeles County Metropolitan Transportation Authority, June 2008, p. 11).

LYNX (ORLANDO, FLORIDA)

The Central Florida Regional Transportation Authority, or LYNX, is the transit agency for the region of Orlando, Florida. More than 1.5 million people live within the area served by LYNX. LYNX operates a fleet of 290 buses that support 146 million passenger miles of travel annually.

LYNX does not have any formal efforts to reduce GHG emissions, although the agency is gaining awareness of GHG issues. No staff person at the agency is assigned to GHG issues. Still, LYNX is planning and implementing strategies that likely will reduce GHG emissions, including expanded service, strategies to increase vehicle passenger loads, strategies to reduce congestion and promote compact development, and strategies to reduce emissions from the agency's fleet and facilities.

LYNX is installing a blending facility for biodiesel at its bus refueling station. The blending facility will consist of a tank for biodiesel and mechanisms to blend the fuel at the point of refueling. With the blending facility, LYNX will gradually convert its entire bus fleet to a mix of 20% biodiesel and 80% conventional diesel, which will replace 800,000 to 1.2 million gallons of conventional diesel fuel every year. The blending facility is funded by a renewable energy grant from the Florida Department of Environmental Protection. LYNX targeted this particular initiative because it requires minimal changes to infrastructure, vehicles, and maintenance procedures. An additional benefit of the program will be greater fuel security for the agency, during times of restricted access to conventional fuels. LYNX will source its biodiesel from a local facility if possible. While GHG emissions reduced were not formally considered in planning and proposing the initiative, LYNX has roughly calculated, using online calculators, that its use of biodiesel could save up to 26 million lb (11,813 metric tons) of CO_2e emissions annually.

LYNX recognizes that reducing these emissions is consistent with state and local policies, even though no such policies place specific requirements on LYNX. Florida's Governor Charlie Crist issued an executive order requiring state agencies to reduce GHG emissions 10% by 2012, increasing to 40% by 2025. Orange County, which is part of LYNX's core service area and is a key funding partner for the agency, also has a GHG reduction policy.

LYNX is considering compiling a GHG emissions inventory. Depending on the cost and level of effort required, the inventory might include emissions from all of the agency's functions, as well as displaced emissions. LYNX would like to be able receive credit for its biodiesel conversion strategy under any future GHG emissions trading schemes, but it is not clear how an emissions inventory might support that goal. The agency may or may not report emissions to a climate registry.

CHAPTER EIGHT

CONCLUSIONS AND FUTURE STUDY NEEDS

Climate change and the greenhouse gas (GHG) emissions that contribute to climate change are a major new environmental concern for the transportation industry. Rising seas, warming temperatures, changes in patterns of precipitation, and increases in severe weather all threaten to reshape our planet's natural systems and to disrupt our cities and rural areas. Releasing more than a quarter of the United States' annual GHG emissions, the transportation sector has a clear role to play in reducing the severity of climate change. Federal regulation requiring the transportation industry to reduce emissions is likely in the near future.

Public transportation stands out as an important partial solution to the problem. Passenger travel in cars and trucks alone generates nearly two-thirds of transportation's GHG emissions in the United States. Public transportation can reduce these emissions by transporting passengers more efficiently than private vehicles can. Transit reduces GHG emissions in four principal ways. Transit displaces emissions from other modes by—

1. Reducing miles traveled in private vehicles,
2. Reducing on-road congestion, and
3. Facilitating compact development patterns that lead to less GHG-intensive travel.

Transit agencies can also:

4. Reduce the emissions that they generate from their vehicles and facilities.

This synthesis reviewed the literature on transit's impact on GHG emissions and on transit strategies to further reduce GHG emissions, and surveyed agencies about their current efforts to reduce GHG emissions. The research concluded the following:

- Many transit agencies are already net reducers of GHG emissions. The net impact of an agency depends on the balance of emissions displaced and emissions released by vehicles and facilities. The U.S. transit industry as a whole produces a net reduction of around 30 million metric tons of carbon dioxide ($MMtCO_2$) annually, or about the same amount emitted by all transportation in the state of Washington.
- Every transit agency surveyed is planning or implementing strategies that can further reduce GHG emissions. Interest in these strategies is widespread across agencies, and agencies generally are aware of the impact such strategies can have on GHG emissions. Types of strategies, along with their prevalence among survey respondents, are as follows:
  - Expanding transit service (78% of respondents are planning or implementing)
  - Increasing vehicle passenger loads (93% of respondents are planning or implementing)
  - Reducing roadway congestion (88% of respondents are planning or implementing)
  - Promoting compact development (70% of respondents are planning or implementing)
  - Alternative fuels and vehicle types (90% of respondents are planning or implementing)
  - Vehicle operations and maintenance (90% of respondents are planning or implementing)
  - Construction and maintenance (73% of respondents are planning or implementing)
  - Reducing energy use in facilities and nonrevenue vehicles (83% of respondents are planning or implementing)
- GHG emissions are still a peripheral concern for transit agencies. Less than half of survey respondents said that reducing GHG emissions was a principal factor in pursuing a given strategy. Increasing ridership, reducing costs, and complying with environmental regulations were more important factors. Agencies are unlikely to pursue strategies for the sole purpose of reducing GHG emissions, but many strategies that reduce GHG emissions have substantial co-benefits.
- Guidance on calculating GHG emissions displaced by transit is still under development. APTA's "Recommended Practice for Quantifying Greenhouse Gas Emissions from Transit" is the first guidance issued for transit agencies. There is particular uncertainty around techniques to estimate the impact of transit on compact development. New and better guidance may lead to greater recognition of displaced emissions by reporting organizations.

- Many agencies have estimated some part of their impact on GHG emissions or have had calculations performed by a partner agency. More than one-third of survey respondents have estimated or are estimating emissions generated by their operations. Nearly half have estimated or are estimating some displaced emissions. Agencies most commonly estimate the mode shift effect of their services. Fewer agencies have estimated their congestion reduction or compact development benefits.
- More research is needed on methodologies to estimate changes in emissions from specific improvements to transit. Most studies that have analyzed the impact of transit on GHG emissions have focused on existing services, and many are limited to analyses at the state or national levels. Very few analyses have covered a full array of strategies that transit agencies can implement to reduce GHG emissions. Even fewer have assessed the cost-effectiveness of such strategies.
- A number of transit agencies have initiated formal or semiformal efforts to address GHG emissions. Several agencies have included GHG emissions in internal sustainability plans or have joined sustainability efforts organized by industry associations. Some agencies have drafted or plan to draft their own climate action plans. More than two-thirds of agencies have participated in talks or joint efforts with other transportation stakeholders on the topic of climate change.
- A study on best practices, opportunities, and challenges for integrating climate change into transit planning would be helpful. Many transit agencies are struggling to fit GHG reduction objectives with their traditional planning objectives. Several recent studies have focused on how metropolitan planning organizations and state departments of transportation integrate climate change into planning objectives and practices. There has been no parallel research on transit agencies and transit planning.
- Transit agencies could benefit from focused research and guidance on new funding opportunities related to GHG emissions. A few agencies are actively considering new funding opportunities that might be created by emissions trading schemes or government grant programs. Such opportunities could become an important source of funding.
- Some agencies are unclear about how reporting their emissions might affect their ability to receive credit for current or future reductions. A research study could describe the risks and opportunities that emissions reporting provides to transit agencies. Such a study might also engage third-party reporting agencies to think more critically about the needs of transit agencies in reporting their emissions.

Transit agencies can expect state and federal legislation and regulation of GHG emissions to affect the way they do business in the future. A growing number of states have legislation that applies to GHG emissions from transportation. Both California and Washington State have legislation requiring a reduction in light-duty vehicle-miles traveled. Washington's law will require most transit agencies to report their GHG emissions beginning in 2010. These regulations present challenges and opportunities to transit agencies. Transit agencies will need to both understand and estimate the impact of their service on GHG emissions. Compiling an inventory of emissions is likely to be an important first step.

Planning for reduced GHG emissions is still a nascent field at transit agencies, but one that is developing rapidly. As regulation of GHG emissions becomes more robust, and as public interest in GHG emissions increases, GHG emissions likely will become a higher priority for transit agencies. Using existing research, agencies can begin to account for the benefits that their services provide to GHG emissions. Transit agencies can also develop new strategies that both reduce GHG emissions and meet other agency priorities.

ABBREVIATIONS

AB Assembly Bill

APC automatic passenger counting (system)

AVLC automatic vehicle location and control (system)

BART San Francisco Bay Area Rapid Transit District

BRT bus rapid transit

CALPIRG California's Public Interest Research Group

CARB California Air Resources Board

CARTA Chattanooga Area Regional Transportation Authority

CBA cost-benefit analysis

CEC California Energy Commission

CH4 methane

CMAQ Congestion Mitigation Air Quality

CNG compressed natural gas

CO_2 carbon dioxide

CO_2e carbon dioxide equivalents

DOT Department of Transportation

EPA Environmental Protection Agency

GHG greenhouse gas

GPS global positioning system

GWP global warming potential

HB House Bill

HFC hydrofluorocarbon

IPCC Intergovernmental Panel on Climate Change

LACMTA Los Angeles County Metropolitan Transportation Authority

LEED Leadership in Environmental Design

LNG liquefied natural gas

LPG liquefied petroleum gas

LRT light rail transit

LYNX Central Florida Regional Transportation Authority (Orlando, Florida)

MPO metropolitan planning organization

MSIP Metro Sustainability Implementation Plan

MTA Metropolitan Transportation Authority

$MMtCO_2$ million metric tons of carbon dioxide

$MMtCO_2e$ million metric tons of carbon dioxide equivalent

N_2O nitrous oxide

NTD National Transit Database

NYMTA New York Metropolitan Transportation Authority

PFC perfluorocarbon

PMT passenger miles traveled

RIP Research in Progress

RTD Denver Regional Transportation District

SB Senate Bill

SAIC Science Applications International Corporation

SEM structural equations modeling

SF_6 sulfur hexafluoride

SFMTA San Francisco Municipal Transportation Agency

SOV single-occupancy vehicle

SUV sport utility vehicle

TOD	transit-oriented development
TTI	Texas Transportation Institute
ULSD	ultra-low-sulfur diesel
VMT	vehicle-miles traveled
VTA	Valley Transportation Authority
WMATA	Washington Metropolitan Area Transit Authority
WSDOT	Washington State Department of Transportation

REFERENCES

1. *Special Report 251: Toward a Sustainable Future*, Transportation Research Board, National Research Council, Washington, D.C., 1997, 275 pp.
2. "Climate Change 2007: The Physical Basis. Summary for Policymakers," Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007 [Online]. Available: http://www.ipcc.ch/SPM2feb07.pdf [accessed Apr. 8, 2009].
3. Hodges, T., *Public Transportation's Role in Responding to Climate Change*, Federal Transit Administration, U.S. Department of Transportation, Washington, D.C., Jan. 2009.
4. Davis, T. and M. Hale, *Public Transportation's Contribution to U.S. Greenhouse Gas Reduction*, Science Applications Internal Corporation, San Diego, Calif., 2007.
5. *Inventory of Greenhouse Gas Emissions and Sinks*: 1990–2007, U.S. Environmental Protection Agency, Washington, D.C., Apr. 2009.
6. Feigon, S., D. Hoyt, L. McNally, R. Mooney-Bullock, S. Campbell, and D. Leach, *TCRP Report 93: Travel Matters: Mitigating Climate Change with Sustainable Surface Transportation*, Transportation Research Board and Center for Neighborhood Technology, National Research Council, Washington, D.C., 2003, 89 pp.
7. Shapiro, R.J. K.A. Hassett, and F.S. Arnold, *Conserving Energy and Preserving the Environment*: *The Role of Public Transportation*, American Public Transportation Association, Washington, D.C., 2002, 39 pp.
8. *Climate Analysis Indicators Tool*, 2005 data, World Resources Institute, Washington, D.C. [Online]. Available: http://cait.wri.org/ [accessed May 14, 2009.]
9. Schrank, D. and T. Lomax, *The 2007 Urban Mobility Report*, Texas Transportation Institute and The Texas A&M University System, College Station, 2007.
10. Bailey, L., P.L. Mokhtarian, and A. Little, *The Broader Connection between Public Transportation, Energy Conservation and Greenhouse Gas Reduction*, ICF International, Fairfax, Va., 2008, 34 pp.
11. Holtzclaw, J., *Does a Mile in a Car Equal a Mile on a Train? Exploring Public Transit's Effectiveness in Reducing Driving*, Sierra Club, San Francisco, Calif., 2000.
12. Evans, J.E., IV, and R.H. Pratt, *TCRP Report 95, Chapter 17: Transit Oriented Development*, Transportation Research Board, National Research Council, Washington, D.C., 2007, 138 pp.
13. Arrington, G.B. and R. Cervero, *TCRP Report 128*: *Effects of TOD on Housing, Parking, and Travel*, Transportation Research Board, National Research Council, Washington, D.C., 2008, 66 pp.
14. Chester, M., *Life-cycle Environmental Inventory of Passenger Transportation in the United States*, Dissertations, Institute of Transportation Studies, University of California, Berkeley, 2008.
15. *Washington State Greenhouse Gas Inventory and Projections, 1990–2020*, Center for Climate Strategies, Washington, D.C., Dec. 2007.
16. Baxandall, P., T. Dutzik, and Joshua Hoen Frontier Group, *A Better Way to Go: Meeting America's 21st Century Transportation Challenges with Modern Public Transit*, California's Public Interest Research Group (CalPIRG) Education Fund, Sacramento, 2008.
17. van de Coevering, P. and T. Schwanen, "Re-evaluating the Impact of Urban Form on Travel Patterns in Europe and North-America," *Transport Policy*, Vol. 13, No. 3, 2006 as cited in Bailey et al., *The Broader Connection between Public Transportation, Energy Conservation and Greenhouse Gas Reduction*, ICF International, Fairfax, Va., 2008.
18. Replogle, M. and H. Parcells, *Linking Bicycle/Pedestrian Facilities with Transit*, National Association of Railroad Passengers and Federal Highway Administration, Washington D.C., 1992. 105 pp.
19. *COMMUTER v.2.0 Model Coefficients*, Office of Transportation and Air Quality, Transportation and Regional Programs Division, Environmental Protection Agency, Washington, D.C., Oct. 2005.
20. Pratt, R.H. and J.E. Evans, IV, *TCRP Report 95: Chapter 10*: *Bus Routing and Coverage*, Transportation Research Board, National Research Council, Washington, D.C., 2004, 74 pp.
21. Bailey, L., *Public Transportation and Petroleum Savings in the U.S.*: *Reducing Dependence on Oil*, ICF International, Fairfax, Va., 2007.
22. Dargay, J.M. and M. Hanly, "Land Use and Mobility," presented at the World Conference on Transport Research, Istanbul, Turkey, 2004. (As cited in Bailey et al., *The Broader Connection between Public Transportation, Energy Conservation and Greenhouse Gas Reduction*, ICF International, Fairfax, Va., 2008.)
23. Evan, J.E., IV, *TCRP Report 95, Chapter 9: Transit Scheduling and Frequency*, Transportation Research

Board, National Research Council, Washington, D.C., 2004, 42 pp.

24. "Transit Station Improvements," Victoria Transport Policy Institute, Victoria, BC, Canada, Aug. 2008 [Online], Available: http://www.vtpi.org/tdm/tdm127.htm [accessed Apr. 8, 2009].

25. ICF International with R. Kuzmyak, *SAFETEA-LU 1808*: *CMAQ Evaluation and Assessment Phase I Final Report*, Prepared for the Federal Highway Administration, Fairfax, Va., Sep. 2008.

26. *Accessing Transit: Design Handbook for Florida Bus Passenger Facilities*, Florida Planning and Development Lab, Department of Urban and Regional Planning, Florida State University, Tallahassee, 2008.

27. "San Francisco Transit Effectiveness Project: SFMTA Board Update," San Francisco Municipal Transportation Agency, Sep. 24, 2007 [Online]. Available: http://www.sfmta.com/cms/mtep/documents/10.10.07%20SFTEP%20Operations%20Review%20ppt.pdf [accessed June 12, 2009].

28. King, R.D., *TCRP Synthesis 49: Yield to Bus—State of the Practice*, Transportation Research Board, National Research Council, Washington, D.C., 2003, 78 pp.

29. Southampton University and the University of Portsmouth Transport Research Laboratory, *Monitoring and Evaluation of a Public Transport Priority Scheme in Southampton*, Transport Research Laboratory, Crowthorne, Berkshire, United Kingdom, 1999.

30. Burgess, E. and A. Rood, *Reinventing Transit: American Communities Finding Smarter, Cleaner, Faster Transportation Solutions*, Environmental Defense Fund, New York, N.Y., 2009.

31. Turnbull, K.P. and R.H. Pratt, *TCRP Report 95, Chapter 11: Transit Information and Promotion*, Transportation Research Board, National Research Council, Washington, D.C., 2004, 71 pp.

32. McCollom. B.E. and R.H. Pratt, *TCRP Report 95, Chapter 12: Transit Pricing and Fares, Traveler Response to Transportation System Changes*, Transportation Research Board, National Research Council, Washington, D.C., 2004, 59 pp.

33. ICF Consulting and Center for Urban Transportation Research, TCRP Report 107: Analyzing the Effectiveness of Commuter Benefits Programs, Transportation Research Board, National Research Council, Washington, D.C., 2005, 75 pp.

34. San Francisco Municipal Transportation Agency, "2009 Climate Action Plan: Draft for Public Review," Dec. 2008.

35. Baltes, M., et al., "Managing Congestion with Integrated Corridor Management," *Mass Transit Magazine*, April/May 2008 [Online]. Available: http://www.masstransitmag.com/print/Mass-Transit/Managing-Congestion-with-Integrated-Corridor-Management/1$5923 [accessed Apr. 4, 2009].

36. Winston, C. and A. Langer, *The Effect of Government Highway Spending on Road Users' Congestion Costs*, Brookings Institute, Washington, D.C., 2004 (As cited in Litman, T., *Evaluating Rail Transit Criticism*, Victoria Transport Policy Institute, Nov. 2008.)

37. Litman, T., *Evaluating Rail Transit Criticism*, Victoria Transport Policy Institute, Victoria, BC, Canada, Nov. 2008.

38. Garrett, T.A., *Light Rail Transit in America: Policy Issues and Prospects for Economic Development*, Federal Reserve Bank of St. Louis, Mo., 2004. (As cited in Litman, T., *Evaluating Rail Transit Criticism*, Victoria Transport Policy Institute, Nov. 2008.)

39. Jacobson, J. and A. Forsyth, "Seven American TODs: Good Practices for Urban Design in Transit-Oriented Development Projects," *Journal of Transportation and Land Use*, Vol. 1, No. 2, Fall 2008, pp. 51–88.

40. *WMATA Joint Development Policies and Guidelines*, Washington Metropolitan Area Transit Authority, Washington D.C., revised Nov. 2008.

41. "Transit-Oriented Development (TOD) Program," Santa Clara Valley Transportation Authority, San Jose, Calif., 2009 [Online]. Available: http://www.vta.org/projects/tod.html [accessed Apr. 8, 2009].

42. TIAX LLC, *Fuel Cycle Assessment: Well-to-Wheels Energy Inputs, Emissions, and Water Impacts*, California Energy Commission, Sacramento, 2007.

43. Fargione, J., J. Hill, D. Tillmand, S. Polasky, and P. Hawthorne, "Land Clearing and the Biofuel Carbon Debt," *Science*, Vol. 319, No. 5867, Feb. 29, 2008, pp. 1235–1238.

44. Searchinger, T.D., et al., "Use of U.S. Croplands for Biofuels Increases Greenhouse Gases Through Emissions from Land-Use Change," *Science*, Vol. 319, No. 5867, Feb. 29, 2008, pp. 1238–1240.

45. Feigon, S., D. Hoyt, L. McNally, R. Mooney-Bullock, S. Campbell, and D. Leach, *TCRP Report 93, Travel Matters: Mitigating Climate Change with Sustainable Surface Transportation*, Transportation Research Board, National Research Council, Washington, D.C., 2003, 59 pp. plus appendices.

46. *Public Transit: A Climate Change Solution*, Issue Paper 16, Canadian Urban Transit Association, Toronto, ON, Canada, Dec. 2005.

47. Gallivan, F., J. Ang-Olsen, and D. Turcheta, "Innovations in State-led Action to Reduce Greenhouse Gas Emissions from Transportation: The State Climate Action Plan," presented at the Annual Meeting of the Transportation Research Board, Washington, D.C., Jan. 13–17, 2008.

48. Boies, A., et al., *Reducing Greenhouse Gas Emissions from Transportation Sources in Minnesota*, University of Minnesota Center for Transportation Studies, Minneapolis, 2008, 60 pp.

49. *Baseline Methodology for Bus Rapid Transit Projects*, Clean Development Mechanism Executive Board, United Nations Framework Convention on Climate Change (UNFCCC), Bonn, Germany, 2006.

50. *Recommended Practice for Quantifying Greenhouse Gas Emissions from Transit: Draft*, Climate Change Standards Working Group, American Public Transportation Association, Washington, D.C., Mar. 2008.

51. Hellinga, B. and J. Cicuttin, "Impacts of New Express Bus Service in Waterloo Region," submitted for the Transportation Association of Canada Annual Conference, Session, Integrating Transit Service into Communities, Saskatoon, Saskatchewan, Oct. 14–17, 2007.

52. Litman, T., *Rail Transit in America: A Comprehensive Evaluation of Benefits*, Victoria Transport Policy Institute, Victoria, BC, Canada, Aug. 31, 2006.

53. *Sacramento Region Blueprint Transportation Land Use Study, Special Report: Preferred Blueprint Alternative*, Sacramento Council of Governments, June 2007.

54. Bartholomew, K., "Integrating Land Use Issues into Transportation Planning: Scenario Planning—Summary Report," University of Idaho, Salt Lake City, and Federal Transit Administration, Washington, D.C., 2005, 34 pp.

55. Wayne, W.S., *Environmental Benefits of Alternative Fuels and Advanced Technology in Transit*, Federal Transit Administration, Washington, D.C., 2007.

56. "Climate Action Plan," San Francisco Municipal Transportation Agency, San Francisco, Calif., 2009 [Online]. Available: http://www.sfmta.com/cms/rcap/capindx.htm [Accessed Apr. 8, 2009].

57. Millard-Ball, A., *Bus Rapid Transit and Carbon Offsets*, Issues Paper prepared for California Climate Action Registry, Los Angeles, Nov. 2008.

58. Ochoa, M.C., "New York City Fleet Upgrades: Conventional Diesel, Hybrid or CNG?" In *Media Res Cost-Benefit Analysis*, Department of City and Regional Planning, University of California, Berkeley, 2008.

59. Nelson/Nygaard Consulting Associates, *BART Actions to Reduce GHG Emissions: A Cost Effectiveness Analysis*, San Francisco Bay Area Rapid Transit District, San Francisco, Calif., Nov. 2008.

60. Litman, T., *Evaluating Public Transit Benefits and Costs*, Victoria Transport Policy Institute, Victoria, BC, Canada, 2008.

61. "Climate Change 101: State Action," Pew Center on Global Climate Change, Arlington, Va., Jan. 2009.

62. *Appendix 4: Leading the Way: Implementing Practical Solutions to the Climate Change Challenge*, Transportation Implementation Working Group, Washington State Climate Action Team, Olympia, 2008.

63. 2009 Pilot Phase of APTA Sustainability Commitment, American Public Transportation Association, Washington, D.C., 2009.

64. *A Low Carbon Future with Public Transport*, International Association of Public Transport, Brussels, Belgium, Jan. 2007.

65. *Greening Mass Transit and Metro Regions: A Synopsis of the Final Report of the Blue Ribbon Commission on Sustainability and the MTA*, Metropolitan Transportation Authority, State of New York, Albany, Feb. 2009.

APPENDIX A
SURVEY

SURVEY PROCESS

An initial generic e-mail was sent to all survey candidates, asking them to fill out the survey within two weeks. An additional reminder e-mail was sent to those agencies that had not yet responded after one week. Finally, one third set of personalized e-mails was sent to those agencies that had not responded after two weeks. In addition, project panel members were asked to follow up with survey candidates as far as possible. Additional assistance was offered to agencies that were having difficulty meeting the specified deadline. The response deadline was ultimately extended by two weeks for agencies that needed extra time.

The survey was administered using on online survey tool, SurveyMonkey. The length of the survey varied depending on participants' responses to individual questions. The survey used "skip logic" to present only the relevant questions to each respondent. For example, if a respondent answered that her agency is pursuing a particular type of strategy, she was presented with two additional questions to gather further detail on those strategies. If not, these questions were automatically skipped. Because the scope of this study is broad, the survey included a large number of questions. Depending on responses to individual questions, a completed survey ranged in length from 37 questions to 72 questions. A few agencies did not complete the entire survey. Participants were provided with the option of completing the survey in either an online or printable format. Completed surveys were accepted from February 13 through March 17, 2009.

SURVEY QUESTIONNAIRE

Current Practices in Greenhouse Gas Emissions Savings from Transit:

Basics

Research Purpose: The purpose of this survey is to gather information about the efforts of transit agencies to reduce greenhouse gas (GHG) emissions from transportation, as part of a Synthesis of Practice being prepared for the Transportation Research Board. The following questions will ask what specific strategies your agency is pursuing and whether you have estimated the emissions savings that will result from strategies. Strategies that reduce GHG emissions typically encompass those that reduce energy consumption or use alternative forms of energy. Based on the results of this survey, some agencies will be asked to serve as case studies. Additional case study research will be conducted by telephone interview.

Survey Instructions: Please expect to spend 30–45 minutes to complete the survey in full. You can exit the survey at any point and return later to fill in skipped questions or change answers to questions. Your responses will be automatically saved. Please note that you must continue the survey from the same computer on which you started.

1. *Please complete the information below.*

   Transit Agency: ______________________________

   Contact Name: ______________________________

   Title: ______________________________

   Email: ______________________________

   Telephone: ______________________________

2. *Is your agency considering how it can reduce GHG emissions from its own operations and/or from the regional transportation footprint (e.g., through formal or informal discussions, quantification of GHG emissions, or participation in state, regional, or local climate planning)?*

☐ Yes

☐ No

Strategies: New Service

The following questions ask about specific strategies that your agency may be planning or implementing.

3. *Are you planning or implementing measures for new, expanded, or increased transit service?*

☐ Yes

☐ No

4. *For each applicable category, are you planning or implementing measures, or both?*

	Planning	Implementing
Expanded route coverage		
Increased service frequency		
Increased hours of operation		
New service types (e.g., BRT or LRT)		
Other (specify below):		

___

5. *What role have GHG emissions played in the agency's decision to pursue these strategies?*

☐ Reducing GHG emissions is a principal factor in the agency's decision to pursue these strategies.

☐ Reducing GHG emissions is a factor in the agency's decision to pursue these strategies,

☐ but not a principal one.

☐ The agency is aware of the potential impact of these strategies on GHG emissions.

☐ The agency has not considered the impact of these strategies on GHG emissions.

☐ Comments

Strategies: Improve Existing Service

6. *Are you planning or implementing strategies that would increase ridership or load factors on existing transit service?*

☐ Yes

☐ No

7. *For each applicable category, are you planning or implementing measures, or both?*

	Planning	Implementing
Transit marketing campaigns		
Provision of real-time transit information or trip planning software		
Improved transit shelters and station stops		
Improved transit access for bicycles and pedestrians		
Improved transit access for the disabled and elderly		
Improved vehicle comfort		
Service improvements, e.g. timed transfers, reduced travel times, improved modal integration		
Changes in fare structures or payment methods		
Safety improvements		
Optimization of existing routes and services		
Other (specify below):		

8. *What role have GHG emissions played in the agency's decision to pursue these strategies?*

- ☐ Reducing GHG emissions is a principal factor in the agency's decision to pursue these strategies.
- ☐ Reducing GHG emissions is a factor in the agency's decision to pursue these strategies, but not a principal one.
- ☐ The agency is aware of the potential impact of these strategies on GHG emissions.
- ☐ The agency has not considered the impact of these strategies on GHG emissions.
- ☐ Comments

Strategies: Compact Development

9. *Are you planning or implementing strategies to promote compact development patterns or transit oriented development (TOD) complementary to transit service?*

- ☐ Yes
- ☐ No

10. *For each applicable category, are you planning or implementing measures, or both?*

	Planning	Implementing
Station area planning		
Coordination with local/regional development decisions		
Other (specify below):		

11. *What role have GHG emissions played in the agency's decision to pursue these strategies?*

- ☐ Reducing GHG emissions is a principal factor in the agency's decision to pursue these strategies.
- ☐ Reducing GHG emissions is a factor in the agency's decision to pursue these strategies, but not a principal one.
- ☐ The agency is aware of the potential impact of these strategies on GHG emissions.

- ☐ The agency has not considered the impact of these strategies on GHG emissions.
- ☐ Comments

Strategies: Congestion Mitigation

12. *Are you planning or implementing strategies that would reduce roadway congestion (e.g., bus lanes, bus pull-outs, signal timing for transit vehicles), in addition to any service changes previously noted?*
    - ☐ Yes
    - ☐ No

13. *For each applicable category, are you planning or implementing measures, or both?*

	Planning	Implementing
Bus-only lanes		
Signal preemption/signal timing for transit vehicles		
Bus pull outs		
Other (specify below):		

14. *What role have GHG emissions played in the agency's decision to pursue these strategies?*
    - ☐ Reducing GHG emissions is a principal factor in the agency's decision to pursue these strategies.
    - ☐ Reducing GHG emissions is a factor in the agency's decision to pursue these strategies, but not a principal one.
    - ☐ The agency is aware of the potential impact of these strategies on GHG emissions.
    - ☐ The agency has not considered the impact of these strategies on GHG emissions.
    - ☐ Comments

Strategies: Vehicle Fuel Efficiency

15. *Are you planning or implementing strategies to improve the fuel efficiency of the existing transit fleet?*
    - ☐ Yes
    - ☐ No

16. *For each applicable category are you planning or implementing measures, or both?*

	Planning	Implementing
Anti-idling policies or technologies		
Vehicle maintenance programs		
Vehicle engine retrofits		
Driver education		
Other (specify below):		

17. *What role have GHG emissions played in the agency's decision to pursue these strategies?*
    - ☐ Reducing GHG emissions is a principal factor in the agency's decision to pursue these strategies.
    - ☐ Reducing GHG emissions is a factor in the agency's decision to pursue these strategies,

- ☐ but not a principal one.
- ☐ The agency is aware of the potential impact of these strategies on GHG emissions.
- ☐ The agency has not considered the impact of these strategies on GHG emissions.
- ☐ Comments

Strategies: Lower Emitting Vehicles

18. *Are you currently operating or planning to purchase low GHG-emitting transit vehicles (e.g., high mpg buses, hybrid buses, CNG buses)?*
    - ☐ Yes
    - ☐ No

19. *For each applicable category, are you planning to purchase, purchasing, or currently operating these vehicles? (Check all the apply.)*

	Planning to Purchase (i.e., in short or long range plan)	Purchasing (i.e., funding secured or orders placed)	Currently Operating
Higher efficiency conventional (ICE) vehicles			
Hybrid-electric vehicles			
Electric vehicles			
Alternative fuel/flux-fuel vehicles (vehicles designed for alternative fuels)			
Vehicle conversion kits			
Other (specify below):			

20. *What role have GHG emissions played in the agency's decision to purchase these vehicles?*
    - ☐ Reducing GHG emissions is a principal factor in the agency's decision to purchase these vehicles.
    - ☐ Reducing GHG emissions is a factor in the agency's decision to purchase these vehicles, but not a principal one.
    - ☐ The agency is aware of the potential impact of these vehicles on GHG emissions.
    - ☐ The agency has not considered the impact of these vehicles on GHG emissions.
    - ☐ Comments

Strategies: Alternative Fuels

21. *Are you using or planning to use alternative fuels in any transit vehicles?*
    - ☐ Yes
    - ☐ No

22. *For each applicable fuel type, are you currently using the fuel? Are you planning to begin or increase use of the fuel?*

	Currently Using	Planning to Begin or Increase Use
Ethanol		
Biodiesel		
Electric vehicles		
Compressed Natural Gas (CNG)		
Liquefied Natural Gas (LNG)		
Liquefied Petroleum Gas (LPG)		
Hydrogen		
Electricity		
Other (specify below):		

23. *Please describe any plans to increase use of alternative fuels in transit vehicles.*

____

24. *What role have GHG emissions played in the agency's decision to use alternative fuels?*

- ☐ Reducing GHG emissions is a principal factor in the agency's decision to pursue these fuels.
- ☐ Reducing GHG emissions is a factor in the agency's decision to pursue these fuels, but not a principal one.
- ☐ The agency is aware of the potential impact of these fuels on GHG emissions.
- ☐ The agency has not considered the impact of these fuels on GHG emissions.
- ☐ Comments

Strategies: Construction and Maintenance

25. *Are you planning or implementing strategies to reduce energy consumption or GHG emissions from your agency's infrastructure construction and maintenance activities?*

- ☐ Yes
- ☐ No

26. *For each applicable category, are you planning or implementing measures, or both?*

	Planning	Implementing
Use of alternative fuels/technologies in non-revenue vehicles		
Changes to construction equipment, vehicles, or fuels		
Use of alternative construction materials		
Recycling construction waste		
Sourcing materials locally		
Other (specify below):		

27. *What role have GHG emissions played in the agency's decision to pursue these strategies?*

- ☐ Reducing GHG emissions is a principal factor in the agency's decision to pursue these strategies.
- ☐ Reducing GHG emissions is a factor in the agency's decision to pursue these strategies, but not a principal one.
- ☐ The agency is aware of the potential impact of these strategies on GHG emissions.
- ☐ The agency has not considered the impact of these strategies on GHG emissions.
- ☐ Comments

Strategies: Other

28. *Are you planning or implementing strategies to reduce energy consumption or GHG emissions from the agency's administrative functions?*

- ☐ Yes
- ☐ No

29. *For each applicable category, are you planning or implementing measures, or both?*

	Planning	Implementing
Employee commuting		
Employee travel		
Energy used in office buildings		
Energy used in maintenance yards		
Other (specify below):		

30. *What role have GHG emissions played in the agency's decision to pursue these strategies?*

- ☐ Reducing GHG emissions is a principal factor in the agency's decision to pursue these strategies.
- ☐ Reducing GHG emissions is a factor in the agency's decision to pursue these strategies, but not a principal one.
- ☐ The agency is aware of the potential impact of these strategies on GHG emissions.
- ☐ The agency has not considered the impact of these strategies on GHG emissions.
- ☐ Comments

Strategies: Additional Detail

31. *Please describe any additional strategies that your agency is planning or implementing to reduce GHG emissions.*

32. *Please describe in more detail your agency's top 3 (if any) strategies intended to reduce GHG emissions, either from operations or from the regional transportation footprint.*

Analyses: Emissions Displaced by Transit

The following questions pertain to techniques used to estimate the impact and cost-effectiveness of GHG reduction strategies. For each strategy that you indicated your agency is considering or implementing, please indicate which if any types of quantitative analysis have been performed.

33. *Have you estimated (or are you estimating) the impact of exiting transit or planned improvements to transit service on VMT, fuel use, or GHG emissions from private autos?*

- ☐ Yes
- ☐ No

34. *Have you forecast (or are you forecasting) the impact of new transit service or improvements to existing service on VMT, fuel use, or GHG emissions from private autos?*

- ☐ Yes
- ☐ No

35. *For each applicable category, which impacts have you analyzed or are your analyzing?*

	Vehicle Miles Traveled in Private Autos	Fuel Use in Private Autos	GHG Emissions from Private Autos
Expanded route coverage			
Increased service frequency			
Increased hours of operation			
New service types (e.g., BRT or LRT)			
Transit marketing campaigns			
Provision of transit information			
Improved transit shelters and station stops			
Improved transit access for bicycles and pedestrians			
Improved transit access for the disabled and elderly			
Improved vehicle comfort			
Service improvements, e.g., timed transfers, reduced travel times, improved modal integration			
Changes in fare structures or payment methods			
Safety improvements			
Optimization of existing routes and services			
Other (specify below):			

___

36. *Briefly describe the analyses and methodologies. Please provide references to guidance documents and any other written documentation.*

___

37. *Have you estimated (or are you estimating) the impact of your existing transit service on VMT, fuel use, or GHG emissions from private autos?*

- ☐ Yes
- ☐ No

38. *Briefly describe the analyses and methodologies. Please provide references to guidance documents and any other written documentation.*

____

39. *Have you estimated (or are you estimating) the additional impact of transit service on travel in private autos due to related land use changes (i.e., compact development facilitated by transit)?*

☐ Yes

☐ No

40. *Briefly describe the analyses and methodologies. Please provide references to guidance documents and any other written documentation.*

____

41. *Have you estimated (or are you estimating) the additional impact of transit service on private auto fuel use or GHG emissions due to reduced congestion?*

☐ Yes

☐ No

42. *Briefly describe the analyses and methodologies. Please provide references to guidance documents and any other written documentation.*

____

Analyses: Emissions Produced by Transit

43. *Have you estimated (or are you estimating) baseline or historical GHG emissions produced by your transit agency?*

☐ Yes

☐ No

44. *Which emissions are included? (Check all that apply.)*

☐ Transit vehicle emissions

☐ Emissions from office buildings

☐ Emissions from maintenance yards

☐ Construction equipment emissions

☐ Emissions associated with production or transportation of materials (embodied emissions)

☐ Other (specify below)

____

45. *Briefly describe the analyses and methodologies. Please provide references to guidance documents and any other written documentation.*

____

46. *Have you reported or are you planning to report your GHG emissions to the Chicago Climate Exchange (CCX), The Climate Registry, or other carbon registries?*

☐ Yes

☐ No

47. *Briefly describe your experience with reporting your GHG emissions to carbon registries.*

____

48. *Have you forecast (or are you forecasting) the impact of any strategies on your transit agency's fuel use or GHG emissions?*

☐ Yes

☐ No

49. *For each applicable strategy category, which impacts have you forecast or are you forecasting?*

	Fuel/Energy Use by the Transit Agency	GHG Emissions from Agency Vehicles and Operations
Expansion of transit service		
Changes in transit vehicle fleets and/or fuel mix		
Energy efficiency measures for office buildings		
Energy efficiency measures for maintenance yards		
Changes to construction equipment and/or fuel mix		
Changes to construction materials		
Other (specify below):		

____

50. *Briefly describe the analyses and methodologies. Please provide references to guidance documents and any other written documentation.*

____

Analyses: Cost Analyses

51. *Have you estimated (or are you estimating) the cost-effectiveness of strategies to reduce VMT or GHG emissions ($/VMT or $/ton)?*

☐ Yes

☐ No

52. *Briefly describe the analyses and methodologies. Please provide references to guidance documents and any other written documentation.*

____

Analyses: Additional Information

53. *Have you used any additional resources or guidance documents, other than those already mentioned, to quantify GHG emissions?*

- ☐ Yes
- ☐ No

54. *What additional resources or guidance documents has your agency used to quantify GHG emissions?*

____

55. *Are you aware of the draft APTA guidance on quantification of GHG emissions?*

- ☐ Yes
- ☐ No

56. *In conducting any analyses of GHG impacts, what challenges have you faced? What additional information, research, and tools are needed?*

____

Planning and Implementation Issues

57. *How are GHG emissions considered in your agency's decision making? (Check all that apply.)*

- ☐ In long term planning
- ☐ In short term planning
- ☐ In plans for specific lines/services
- ☐ Informally considered
- ☐ Not considered
- ☐ Other (specify below)

____

58. *Has your agency adopted or begun to develop policies to reduce GHG emissions (e.g., reduction targets or a climate plan)?*

- ☐ Yes
- ☐ No

59. *Please describe these policies.*

____

60. *Is your agency affected by any state, regional, or local GHG policies?*

- ☐ Yes
- ☐ No

61. *What are the relevant policies? How is your agency affected by them?*

____

62. *Has your agency discussed climate change issues with state, regional, or local governments?*

☐ Yes

☐ No

63. *Briefly describe the discussion's scope and context. Which agency initiated discussions?*

____

64. *What are the greatest challenges your agency faces in reducing GHG emissions? (Rank all that apply, where 1 is the greatest challenge.)*

	Rank
Difficulty describing the GHG benefits of strategies to stakeholders/decisions makers	–
Insufficient partnerships with other regional players (e.g., cities, MPOs, other transit agencies)	–
Lack of staff know-how	–
Technical barriers to implementation of emissions reduction strategies	–
Planning mechanisms/procedures do not consider GHG emissions	–
Lack of staff capacity (person-hours)	–
Lack of organizational mandate/policy	–
Lack of appropriate tools, data, or analysis techniques	–
Lack of funding	–
Other (specify below):	–

____

65. *What does your agency need to overcome these challenges (e.g., specific training, research, additional staff hires, etc.)?*

____

66. *Does your agency have a designated staff person to address climate change/GHG emissions issues?*

☐ Yes

☐ No

67. *In what department is the staff person housed?*

____

68. *Does your agency have any additional efforts to reduce GHG emissions, other than those already mentioned? Please describe.*

____

Synthesis Report

69. *If selected, would you be willing to serve as a case study for this TCRP Synthesis report?*

- ☐ Yes
- ☐ No

70. *Do you have any suggestions of other agencies that we should survey and/or consider as case studies? Please provide contact names.*

Agency Name/
Contact Name: ______________________________

Agency Name/
Contact Name: ______________________________

Agency Name/
Contact Name: ______________________________

71. *What information would you most like to see provided in this TCRP Synthesis of Practice?*

____

72. *Please describe. Please provide any additional comments below.*

____

Thank You!

If you would like to submit additional information or documents, or you have questions or comments about this survey, please contact Frank Gallivan (fgallivan@icfi.com). Thank you!

APPENDIX B
SURVEY PARTICIPANTS

Transit Agency	Region	State/Province	Respondent Title
Sun Tran	Tucson	AZ	Environmental Manager
TransLink	Vancouver	British Columbia	VP Corporate and Public Affairs
Los Angeles County Metropolitan Transportation Authority (LACMTA)	Los Angeles	CA	Environmental Compliance and Services Department Manager
AC Transit	Oakland	CA	Environmental Engineer
Sacramento Regional Transit District	Sacramento	CA	Director of Planning
San Francisco Bay Area Rapid Transit District	San Francisco	CA	Deputy Planning Manager - Stations
San Francisco Municipal Transportation Agency (SFMTA)	San Francisco	CA	Manager, Environmental Planning
Santa Clara Valley Transportation Authority (VTA)	San Jose	CA	Manager, Environmental Programs & Resources Mgmt
Foothill Transit	West Covina	CA	Director of Operations and Maintenance
Denver Regional Transportation District (RTD)	Denver	CO	Civil Engineering Project Manger
Washington Metropolitan Area Transit Authority	Washington	DC	Manager, Environmental Management & Industrial Hygiene
Space Coast Area Transit (SCAT)	Brevard County	FL	Director
Lee County Transit	Ft. Myers	FL	Transit Director
Regional Transit System (RTS)	Gainesville	FL	Transit Director
Jacksonville Transportation Authority	Jacksonville	FL	Assistant Director of Mass Transit
Ocala/Marion Transit Inc. DBA SunTran	Ocala	FL	General Manager
Okaloosa County BCC	Okaloosa County	FL	Transit Coordinator & Grants Manager
Central Florida Regional Transportation Authority d/b/a LYNX	Orlando	FL	Government Affairs Project Manager
Palm Tran	Palm Beach County	FL	Maintenance Manager
Bay Town Trolley	Panama City	FL	Senior Planner
Pinellas Suncoast Transit Authority	Pinellas	FL	Director of Planning
Council On Aging of St. Lucie Inc., Community Transit	Port St. Lucie	FL	Transit Vehicle Maintenance & Security Director
Sarasota County Area Transit (SCAT)	Sarasota County	FL	General Manager

Transit Agency	Region	State/Province	Respondent Title
St Johns County Public Bus Service, The Sunshine Bus Company	St. Johns County	FL	Transit Planner
StarMetro	Tallahassee	FL	Superintendent of Transit
GoLine Indian River Transit	Vero Beach	FL	CEO/Pres.
Chicago Transit Authority	Chicago	IL	Project Manager, Planning and Development
Transit Authority of River City (TARC)	Louisville	KY	Director of Planning
Massachusetts Bay Transportation Authority	Boston	MA	Director of Environmental Affairs
Montgomery County DOT, Ride On Transit Services	Rockville	MD	Division Chief
Charlotte Area Transit System (CATS)	Charlotte	NC	Grants Management Analyst
NJ TRANSIT	Newark	NJ	Director, Energy and Sustainability
Southwest Ohio Regional Transit Authority (SORTA)	Cincinnati	OH	Director fleet & facilities
TriMet	Portland	OR	Strategic Planning Analyst
Southeastern Pennsylvania Transportation Authority (SEPTA)	Philadelphia	PA	Director, Business Development
Metropolitan Transit Authority Of Harris County	Houston	TX	Associate Vice President
Utah Transit Authority	Salt Lake City	UT	Manager of Safety and Environmental Protection
Hampton Roads Transit (HRT)	Hampton	VA	Director of Energy Management and Sustainability
King County Metro Transit	Seattle	WA	Senior Project Manager
Sound Transit	Seattle	WA	Environmental Compliance Manager
Community Transit	Snohomish County	WA	Risk Management Analyst - Environmental

APPENDIX C

GREENHOUSE GAS EMISSIONS SAVINGS FROM SELECTED TRANSIT AGENCIES

Results provided in this appendix are drawn from a 2008 study by CALPIRG. That study calculated emissions reductions for a sample of transit agencies using data from the National Transit Database and the Texas Transportation Institute's Urban Mobility Report. Calculations accounted for mode shift, congestion reduction, and compact development impacts.

Agency Name	Agency Abbreviation	State	Annual Carbon Dioxide Emission Reductions (thousand metric tons)
MTA New York City Transit	NYCT	NY	10,470
Washington Metropolitan Area Transit Authority	WMATA	MD	1,852
San Francisco Bay Area Rapid Transit District	BART	CA	1,711
Chicago Transit Authority	CTA	IL	1,293
Massachusetts Bay Transportation Authority	MBTA	MA	1,213
New Jersey Transit Corporation	NJ TRANSIT	NJ	1,201
MTA Long Island Rail Road	MTA LIRR	NY	950
Los Angeles County Metropolitan Transportation Authority	LACMTA	CA	862
Metro-North Commuter Railroad Company, dba: MTA Metro-North Railroad	MTA-MNCR	NY	725
Southeastern Pennsylvania Transportation Authority	SEPTA	PA	713
Metropolitan Atlanta Rapid Transit Authority	MARTA	GA	644
Northeast Illinois Regional Commuter Railroad Corporation	Metra	IL	632
Port Authority Trans-Hudson Corporation	PATH	NJ	395
Maryland Transit Administration	MTA	MD	245
Tri-County Metropolitan Transportation District of Oregon	TriMet	OR	274
San Diego Trolley, Inc.	MTS	CA	281
Dallas Area Rapid Transit	DART	TX	164
San Francisco Municipal Railway	MUNI	CA	198
Miami-Dade Transit	MDT	FL	130
Southern California Regional Rail Authority	Metrolink	CA	178
Metro Transit		MN	88

Agency Name	Agency Abbreviation	State	Annual Carbon Dioxide Emission Reductions (thousand metric tons)
Bi-State Development Agency	METRO	MO	125
Utah Transit Authority	UTA	UT	121
Metropolitan Transit Authority of Harris County, Texas	Metro	TX	104
Denver Regional Transportation District	RTD	CO	85
Sacramento Regional Transit District	Sacramento RT	CA	99
Peninsula Corridor Joint Powers Board	PCJPB	CA	106
The Greater Cleveland Regional Transit Authority	GCRTA	OH	73
King County Department of Transportation - Metro Transit Division King County Metro		WA	88
Port Authority Transit Corporation	PATCO	NJ	88
Academy Lines, Inc.		NJ	73
City and County of Honolulu Department of Transportation Services	DTS	HI	54
Northern Indiana Commuter Transportation District	NICTD	IN	56
Orange County Transportation Authority	OCTA	CA	35
Santa Clara Valley Transportation Authority	VTA	CA	53
Central Puget Sound Regional Transit Authority	ST	WA	50
Virginia Railway Express	VRE	VA	53
Metropolitan Suburban Bus Authority, dba: MTA Long Island Bus		NY	20
Hudson Transit Lines, Inc.	Short Line	NJ	47
Port Authority of Allegheny County	Port Authority	PA	22
Regional Transportation Commission of Southern Nevada	RTC	NV	32
MTA Bus Company	MTABUS	NY	-72
Pace - Suburban Bus Division	PACE	IL	33
South Florida Regional Transportation Authority	TRI-Rail	FL	25
Suburban Transit Corporation	Coach USA	NJ	34
City of Detroit Department of Transportation	DDOT	MI	29
Southwest Ohio Regional Transit Authority	SORTA / Metro	OH	15
North County Transit District	NCTD	CA	24

San Diego Metropolitan Transit System	MTS	CA	1
Westchester County Bee-Line System The Bee-Line System		NY	23

Source: Baxandall, P., T. Dutzik, and Joshua Hoen Frontier Group, *A Better Way to Go: Meeting America's 21st Century Transportation Challenges with Modern Public Transit*, California's Public Interest Research Group (CALPIRG) Education Fund, 2008.

Abbreviations used without definition in TRB Publications:

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	Air Transport Association
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
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
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
SAE	Society of Automotive Engineers
SAFETY-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
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

TRANSPORTATION RESEARCH BOARD
500 Fifth Street, N.W.
Washington, D.C. 20001

ADDRESS SERVICE REQUESTED

THE NATIONAL ACADEMIES™

Advisers to the Nation on Science, Engineering, and Medicine

The nation turns to the National Academies—National Academy of Sciences, National Academy of Engineering, Institute of Medicine, and National Research Council—for independent, objective advice on issues that affect people's lives worldwide.
www.national-academies.org

ISBN 978-0-309-14303-5

90000

9 780309 143035