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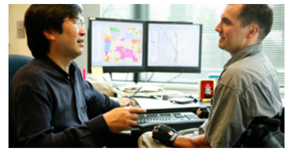





Climate Smart Communities: Scenarios Project

Strategy Toolbox

for the Portland metropolitan region

Review of the latest research on greenhouse gas emissions reduction strategies and the benefits they bring to the region

October 2011

Metro | *Making a great place*

About Metro

Clean air and clean water do not stop at city limits or county lines. Neither does the need for jobs, a thriving economy, and sustainable transportation and living choices for people and businesses in the region. Voters have asked Metro to help with the challenges and opportunities that affect the 25 cities and three counties in the Portland metropolitan area.

A regional approach simply makes sense when it comes to making decisions about how the region grows. Metro works with communities to support a resilient economy, keep nature close by and respond to a changing climate. Together we're making a great place, now and for generations to come.

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Acknowledgements

This document will be regarded as a resource throughout the Climate Smart Communities Scenarios process to evaluate potential strategies to reduce our GHG emissions.

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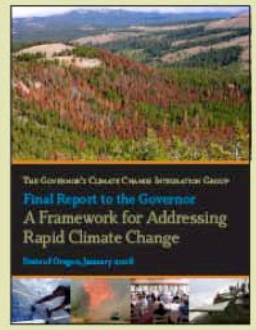
I. PURPOSE AND LEGISLATIVE BACKGROUND

Purpose

The purpose of the Strategy Toolbox (Toolbox) is to summarize research related to land use and transportation strategies that can be applied to reduce greenhouse gas (GHG) emissions from light duty vehicles in the Portland metropolitan region. A variety of strategies are available, many of which are already being implemented to realize the 2040 Growth Concept and the aspirations of communities throughout the region.

Created for the Climate Smart Communities Scenarios Project, this report will be used to develop a common understanding of potential policy options and the range of strategies available for reducing GHG emissions from light duty vehicles in the region. It provides information useful for the region's decision-makers to discuss the trade-offs and choices presented by the most effective strategies, including their co-benefits, synergy with each other and implementation considerations. This report and findings from regional-level scenarios analysis will be used to recommend policy options and packages of strategies for further evaluation in 2012. The findings and recommendations also will be included in a progress report to the Oregon State Legislature in January 2012.



Greenhouse gas goals adopted by the Oregon Legislature and Governor Kulongoski in HB 3543:

- **Short-term:** by 2010, stop increases in greenhouse gas emissions
- **Medium-term:** by 2020, reduce greenhouse gas emissions to 10 percent below 1990 levels
- **Long-term**: by 2050, reduce greenhouse gas emissions to 75 percent below 1990 levels.

Oregon greenhouse gas emissions reduction goals

Since 2006, the state of Oregon has initiated a number of actions to respond to mounting scientific evidence that shows the earth's climate is changing. As one of five states participating in the Western Climate Initiative, Oregon has signaled a long-term commitment to significantly reduce greenhouse gas emissions. In 2007, the Oregon Legislature established statewide goals for GHG emissions. The goals require stopping increases in emissions by 2010, a ten percent reduction below 1990 levels by 2020, and at least a 75 percent reduction below 1990 levels by 2050. The goals apply to all emission sectors, including energy production, buildings, solid waste and transportation.

In 2009 the Oregon Legislature passed House Bill 2001 (HB 2001), directing Metro to "develop two or more alternative land use and transportation scenarios" by January 2012 that are designed to reduce GHG emissions from light duty vehicles to help meet the state's overall GHG emission goals. Light duty vehicles are less than 10,000 pounds in gross weight, and include cars, pickups, sport utility vehicles and some delivery vehicles.

On May 19, 2011, the Oregon Land Conservation and Development

Commission (LCDC) approved the Metropolitan Greenhouse Gas Emissions Reduction Target Rule. The rule identifies specific per capita GHG emissions reduction targets for each of Oregon's six metropolitan areas. Assuming significant advancements in vehicle fleet, technologies and fuels to reduce GHG emissions, it calls for the Portland region to reduce per person GHG emissions by an additional 20 percent below 2005 emission levels by the year 2035 through land use and transportation strategies. This means the region needs to build, and eventually adopt, a preferred alternative comprising a set of land use and transportation strategies that will reduce GHG emissions an additional 20 percent below what we can anticipate from fuel, fleet and technology improvements. The state LCDC target is intended to guide the region as it conducts land use and transportation scenario planning to help move toward the state's overall GHG emissions goal.

Table 1 summarizes the state goals and regional GHG emissions reduction targets.

Table 1. GHG emissions reduction goals

Area	Baseline	2010 Reduction goal	2020 Reduction goal	2035 Reduction goal	2050 Reduction goal
Portland metropolitan region (per capita)	2005 emissions levels			20% below 2005 levels	
Oregon (total)	1990 emissions levels	Stop increases in GHG emissions	10% below 1990 levels		75% below 1990 levels

The Oregon Department of Transportation (ODOT) and the Oregon Department of Land Conservation and Development (DLCD) must report to the Oregon legislature by February 1, 2012 on the progress of Metro's scenario planning effort and the LCDC targets. HB 2001 also requires:

- Metro to adopt a preferred alternative in 2014 that meets the light duty vehicle GHG emissions reduction target for the region, and
- Local governments within Metro's jurisdiction to amend their comprehensive plans and land use regulations to implement the adopted preferred alternative.

Oregon Sustainable Transportation Initiative

The Oregon Sustainable Transportation Initiative (OSTI)[1] is the integrated statewide effort to reduce GHG emissions from transportation while also considering ways to improve the built

[1] For more information on the Oregon Sustainable Transportation Initiative, please refer to the following web site: http://www.oregon.gov/ODOT/TD/OSTI/

environment for healthier, more livable communities and greater economic opportunity for everyone. It has four major components:

- development of a statewide transportation strategy,
- adoption of rules that set GHG emission reduction targets for the state's six metropolitan areas,
- development of scenario planning guidelines, and
- creation of a toolkit for use by local governments.

ODOT and DLCD are leading this effort pursuant to Senate Bill 1059, passed by the Oregon Legislature in 2010.

II. REGIONAL PLANNING FRAMEWORK

Climate Smart Communities Scenarios Project

Regional and local leaders in the Portland region agree that Oregon must provide leadership in addressing climate change. The Climate Smart Communities Scenarios project (Scenarios Project) supports this goal by supplementing state efforts and OSTI with a collaborative regional effort that will advance local aspirations and implementation of the 2040 Growth Concept.

There are three phases to the Scenarios Project. Phase 1 consists of testing strategies and identifying policy options for further evaluation in Phase 2. Phase 2 will include developing and evaluating alternative land use and transportation scenarios for achieving GHG emission reductions. Phase 3, taking place during 2013 and 2014, will entail selection of a preferred alternative and implementation of recommended policies at the regional level.

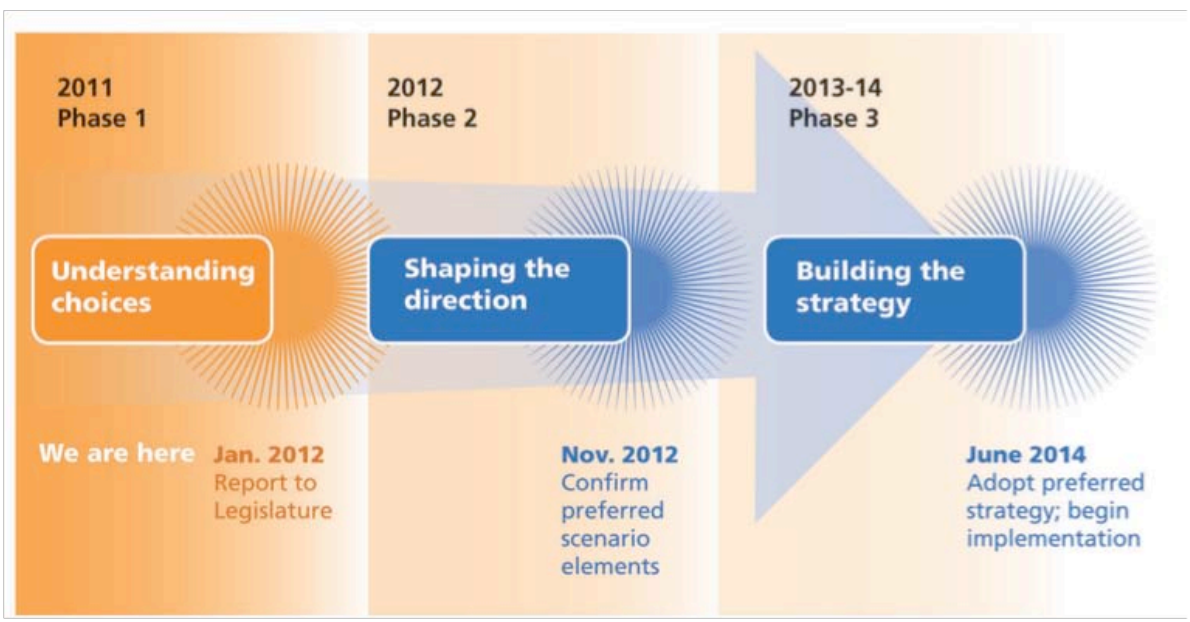


Figure 1. Climate Smart Communities Scenarios Timeline

Phase 1: Understanding choices

During 2011, the region will use scenario planning and the research summarized in this document to determine the combinations of land use and transportation strategies that are most promising for meeting the region's GHG emissions reduction target for cars, small trucks and sport utility vehicles. Several strategies will be tested and evaluated to further the knowledge about their potential application in the region.

The analysis will be used to identify potential policy options and provide information useful for policymakers and stakeholders to discuss the trade-offs and choices presented by the most effective GHG emission reduction strategies during Fall 2011. The regional policy discussion will shape the findings and packages of potential strategies recommended for further evaluation in 2012, and will be included in a progress report to the Oregon State Legislature in January 2012.

Phase 2: Shaping the direction

In 2012, the region will examine the most promising strategies by exploring scenarios in communities around the region in a more customized way. Local government aspirations will be considered and incorporated into the alternative scenarios along with lessons learned from Phase 1. In addition, recommendations from several planning efforts underway in the region – including the Portland Plan, the Southwest Corridor Plan, the East Metro Connections Plan and the Regional Active Transportation Action Plan – will also be incorporated.

This approach allows for pursuing different strategies that support distinct community goals across the region, in recognition that implementation may be different in each community. This phase will also identify the benefits, impacts and costs (and cost savings) associated with different scenarios across environmental, economic and equity goals, and use case studies to illustrate effects in communities around the region. The alternative scenarios analysis will lead to development of a draft preferred alternative by the end of 2012, and the adoption of the preferred alternative during Phase 3.

Phase 3: Building the strategy

In 2013 and 2014, the region will collaboratively build and adopt a preferred alternative that recognizes community values and local differences while moving toward regional and state goals. This will entail analysis and selection of a preferred set of land use and transportation strategies to be implemented through state, local and regional plans, policies and investments. The information acquired throughout the Scenarios Project and embodied in the preferred alternative will provide policy guidance and requirements for the next update of the Regional Transportation Plan, Metro's next capacity analysis and ordinance, the Regional Framework Plan and Metro functional plans, which direct local government implementation of regional policies.

2040 Growth Concept and the six desired outcomes

In 1995, the region established a course for growth with the adoption of the 2040 Growth Concept. Metro and its partners have collaborated to help communities realize their local aspirations while moving the region toward its goals: making the region a great place to live, work and play, while balancing growth with sound environmental, social and economic strategies. The Growth Concept provided a guide to actively manage the growth of the region by encouraging development in centers, corridors and employment areas and maintaining a tight urban growth boundary.

The result is efficient land development, vibrant downtowns and mainstreets, a mix of transportation choices and a growing legacy of protecting the farms, forests and natural areas that are so critical to the quality of life residents of the region enjoy.

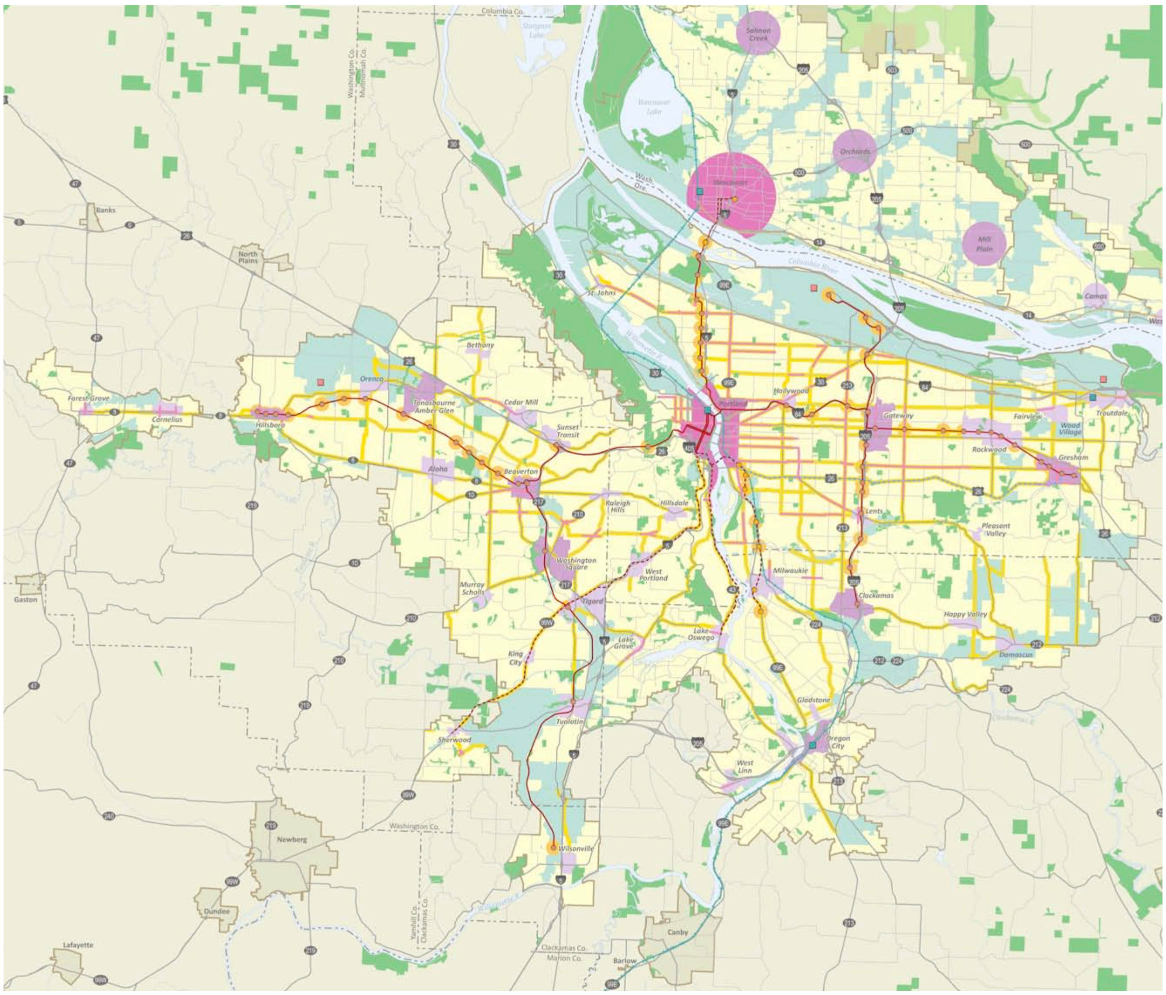


Figure 2. The 2040 Growth Concept is the region's blueprint for the future, guiding growth and development based on a shared vision to create livable, prosperous, equitable and climate smart communities now and for future generations to come.

Over the 15 years since the 2040 Growth Concept was adopted, local governments have taken steps to create vibrant, safe and livable communities by amending their comprehensive plans, providing financial assistance and investing in essential public amenities to spur private investment and the creation of jobs.

In 2010, Metro continued to support the 2040 vision and community aspirations by adopting an outcomes-based blueprint for the future – the Community Investment Strategy. This provides the policy foundation for better integrating land use decisions with transportation investments to achieve the region's 2040 vision and six desired outcomes as well as the state climate goals.

Figure 3. The region's six desired outcomes – endorsed by city and county elected officials and approved by the Metro Council in December 2010.

While these efforts are commendable, additional policies and strategies are needed to reduce GHG emissions from the transportation sector. GHG emissions reductions are not only a requirement of the state; they are also instrumental in realizing the vision of the 2040 Growth Concept. Ultimately, a preferred alternative will be adopted by the Metro Council that helps fulfill local government aspirations, meet state climate goals, and realize the region's adopted six desired outcomes.

Attributes of great communities

Goals for the region endorsed by city and county elected officials and approved by the Metro Council in December 2010.

Vibrant communities

People live, work and play in vibrant communities where their everyday needs are easily accessible.

Leadership on climate change

The region is a leader in minimizing contributions to global warming.

Economic prosperity

Current and future residents benefit from the region's sustained economic competitiveness and prosperity.

Clean air and water

Current and future generations enjoy clean air, clean water and healthy ecosystems

Transportation choices

People have safe and reliable transportation choices that enhance their quality of life.

Equity

The benefits and burdens of growth and change are distributed equitably.

Regional Transportation Plan

The Regional Transportation Plan (RTP) is the blueprint that guides investments in the region's transportation system. The plan focuses on outcomes and achieving the region's 2040 Growth Concept vision, and recommends how to invest more than $20 billion in anticipated federal, state and local transportation funding in the Portland metropolitan area over the next 25 years. The following elements of the plan will help inform the Scenarios Project:

The **Regional Transportation System Management and Operations Plan** (TSMO) includes a set of integrated transportation strategies intended to improve the performance of existing transportation infrastructure. TSMO addresses transportation goals such as mobility, reliability, safety and accessibility through a combination of transportation system management systems, transportation demand management, traffic incident management, and traveler information. These functional components are also strategies included in the toolbox and are an important consideration to reducing vehicle miles traveled (VMT) and associated GHG emissions.

The RTP also includes a new **Mobility Corridors** policy to guide consideration of land use and transportation in each of the region's 24 major travel corridors. The policy addresses the region's land uses served by an integrated network of freeways, highways, arterial streets, bicycle corridors, walking corridors, high capacity transit routes, and frequent bus service routes. The primary function of the corridors network is metropolitan mobility – moving people and goods between different parts of the region and, in some corridors, connecting the region with the rest of the state and beyond. The policy will provide a useful framework for developing and evaluating alternative scenarios as a part of Phase 2 of the

The Scenarios Project is one element of a larger set of climate-related initiatives at Metro collectively known as **Climate Smart Communities**:

Regional Greenhouse Gas Emissions Inventory
In 2010, Metro completed a regional GHG emissions inventory for the year 2006. The inventory establishes a snapshot of the region's carbon footprint to focus planning and monitoring efforts to achieve long-term GHG reductions.

Greenhouse Gas Emissions Assessment Toolkit
Metro developed a regional GHG Emissions Assessment Toolkit that establishes a framework for regional climate impact assessments and provides consistent guidance on analysis methods, reporting, and evaluation of Metro projects, programs, and policies.

Climate Leadership Initiative
Metro participated in the Climate Leadership Initiative, completed in January 2010, which engaged local experts and stakeholders on how to prepare the lower Willamette Valley River Basin for climate change impacts.

Climate Prosperity Strategy
Metro worked with local governments, businesses, educational institutions, and the Portland Oregon Sustainability Institute to develop the 2011 Portland Metro Climate Prosperity Strategy—a 'greenprint' for integrating climate change policy and economic development into a single strategy.

Scenarios Project.

Another part of the RTP, the **Regional Freight Plan**, defines goals, strategies and actions designed to guide the stewardship of our multimodal regional freight infrastructure and protecting access to critical industrial lands. The plan also addresses goals for freight mobility, accessibility and travel time reliability through a combination of strategies that will also reduce transportation costs for businesses and individuals, while reducing freight's environmental and community impacts. While the Scenarios Project is focused on GHG emissions from light-duty vehicles, the Regional Freight Plan and potential benefits and impacts to freight will be considered as part of the Scenarios Project to understand how different GHG reduction approaches could affect the cost of moving freight and other freight-related outcomes, including implications for the region's economy.

The **Regional High Capacity Transit System Plan** (HCT) is designed to focus on the frequent, fast and high capacity element of the public transit system. High capacity transit is characterized by exclusive right of way and routes with fewer stops. The plan is intended to support and enhance the goals of the 2040 Growth Concept and the RTP. To accomplish these goals, the plan prioritizes 18 corridors based on planned land uses, community values, environmental benefits, economic potential and deliverability. Due to the number of identified future HCT corridors, there are many choices and levels of transit service that could be evaluated. Information from the HCT Plan will be used to identify potential transit strategies that support various land use intensities and locations in Phase 2 of the Scenarios Project.

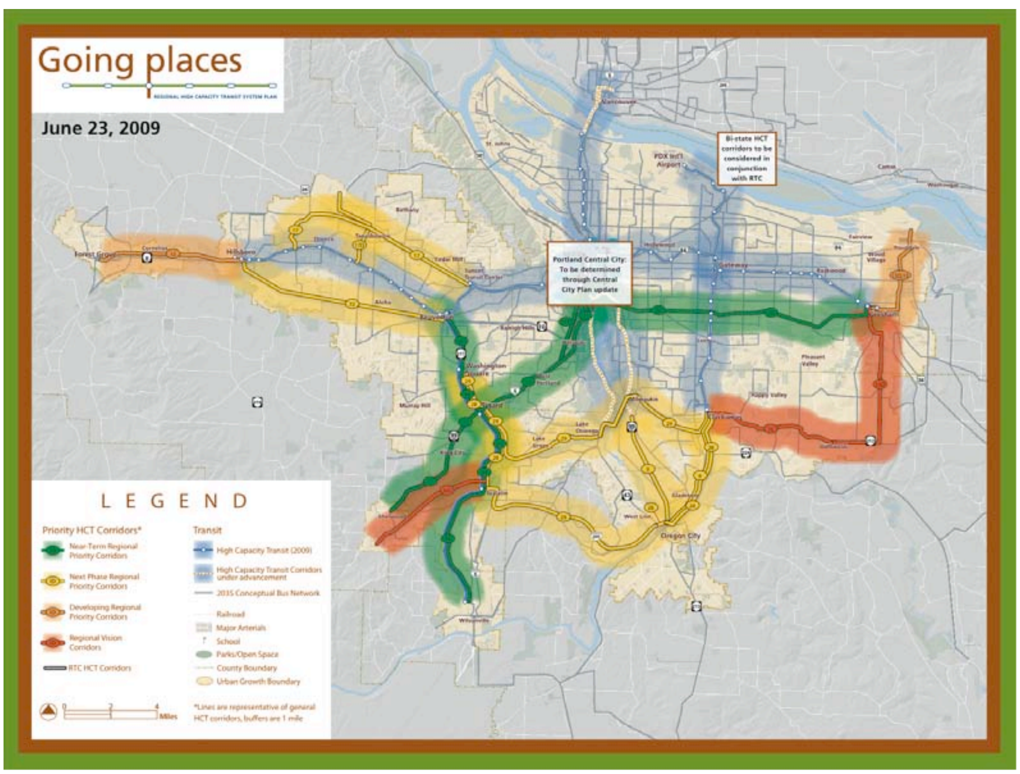


Figure 4. The Regional High Capacity Transit System Plan prioritizes future investments in frequent, fast, and high capacity public transit services throughout the Metro region.

Regional greenhouse gas emissions inventory

In 2010, Metro completed a GHG emissions inventory for the region. This inventory establishes a snapshot of the region's carbon footprint assisting Metro in focusing its planning and monitoring efforts to achieve long-term GHG emissions reductions. The total estimated emissions from activities associated with the region are 31 million metric tons for 2006.[2]

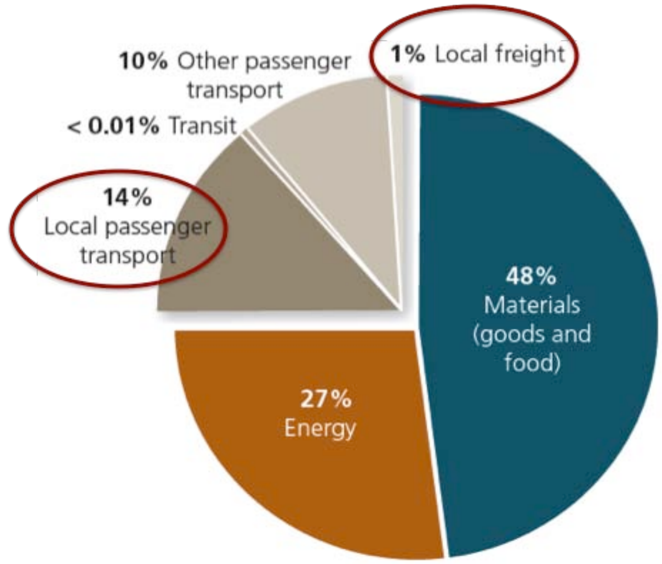


Figure 5. Regional emission sources (2006)

The three major emission sources are transportation (25 percent), energy (27 percent) and materials (48 percent). Transportation emissions come mainly from on-road vehicles and air travel, with smaller shares from rail, marine, and mass transit.

Transportation emissions are traditionally thought to result from three main factors: vehicle technology, fuel characteristics, and VMT. Dramatic progress in vehicle emissions control technology and fuel quality has reduced criteria pollutant emissions over the past 30 years. While we must continue to make progress on vehicle technologies and fuels – and the policies to implement them – we must also assess the extent to which we can reduce VMT.

The light duty vehicle transport component is responsible for approximately 15 percent of the region's GHG emissions.[3] These local passenger transport categories include cars, pickups, sport utility vehicles, and local freight vehicles that weigh less than 10,000 pounds. Light duty vehicles are the subject of the state law that the Scenarios Project will address in the Portland metropolitan region.

State law requires Metro to show how the region can meet the goal of 20 percent per capita reduction from light duty vehicles, in addition to what we can anticipate from technology and fleet improvements. Therefore, it is important to realize and address the fact that approximately 85 percent of the region's GHG emissions come from other sources. For this reason, the intent of the Scenarios Project is, in part, to use the scenario planning process to help determine how land use and transportation strategies can result in outcomes that meet other goals as well as help reduce greenhouse gas emissions from other sectors such as buildings. As referenced earlier, the region's six desired outcomes will guide the strategies and evaluation process.

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[2] Measured and stored at standard atmospheric pressure, one metric ton of CO_2 occupies a cube approximately the size of a three-story building (27 feet x 27 feet x 27 feet).
[3] The EPA has calculated that the annual emissions from a typical passenger vehicle should be equated to 5.5 metric tons of CO_2.

The project will evaluate the relationship between changes to urban form and transportation investments, and their potential impacts on VMT and GHG emissions. The evaluation will assess the costs, benefits and co-benefits of GHG reduction strategies and other indicators such as avoided infrastructure costs, fuel savings, transit operating costs and ridership, water use, economic development, household costs, social equity, and public health. The outputs will include how a set of strategies performs relative to GHG emissions, VMT, energy consumption, household travel costs, natural resource impacts, and public health impacts, among others.

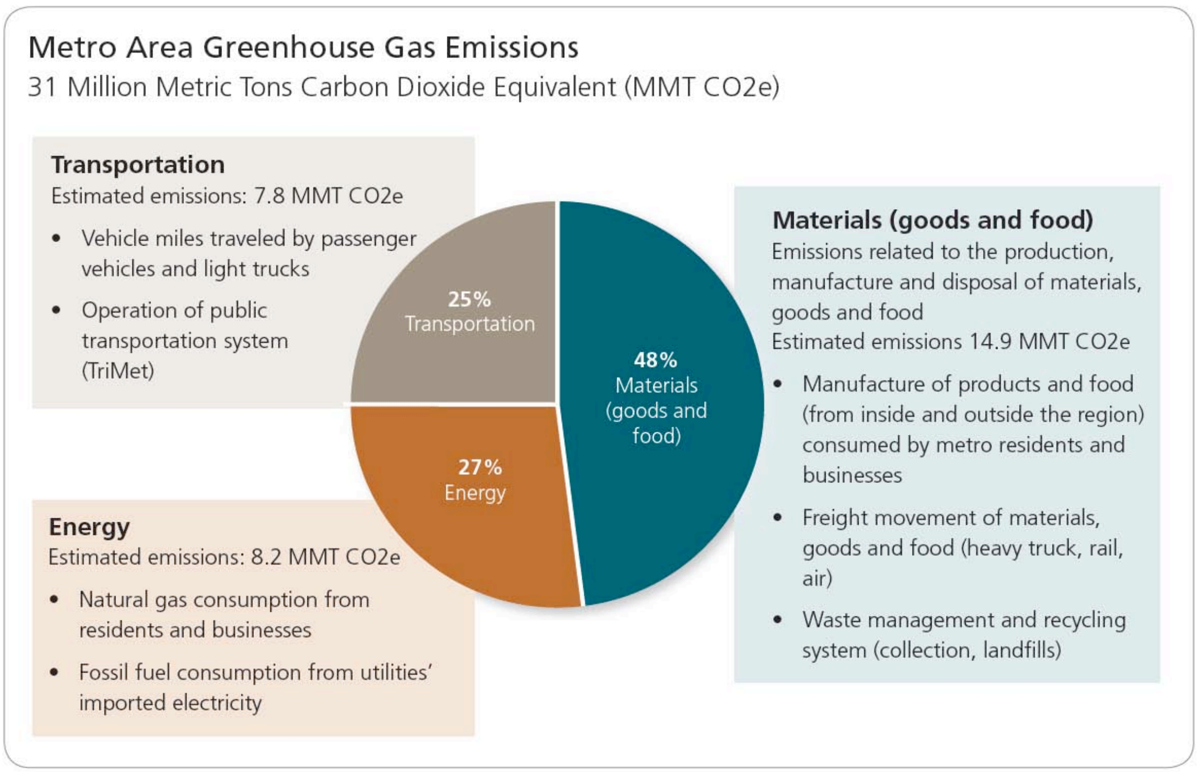

Figure 6. Explanation of regional emission sources (2006)

III. GREENHOUSE GAS REDUCTION STRATEGIES

The Toolbox is a review of the latest research on land use and transportation strategies that can reduce travel demand and the emissions associated with light-duty vehicles. Specifically, the Toolbox identifies such strategies and summarizes research on potential emissions reduction and other benefits to the region. Chapter V includes the list of resources used for this review.

The strategies covered in this chapter are organized into five sections:

COMMUNITY DESIGN


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COMMUNITY DESIGN STRATEGIES
Mixed-use development in centers and corridors
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PRICING


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PRICING STRATEGIES
Parking pricing, tolls, fees and insurance
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MARKETING AND INCENTIVES


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MARKETING AND INCENTIVES STRATEGIES
Education, marketing and commuter programs
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MANAGEMENT


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MANAGEMENT STRATEGIES
Traffic and incident management
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FLEET AND TECHNOLOGY


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FLEET AND TECHNOLOGY STRATEGIES
Fleet mix, turnover, technology and fuels
Metro

These categories reflect the ones that Metro will use to develop scenarios for testing possible futures for the region in order to meet the state goal of 20 percent per capita reduction of GHG emissions by 2035. Metro used ODOT's Greenhouse Gas State Transportation Emissions (GreenSTEP) model to perform the analysis in Phase 1. This scenario analysis, conducted with the help of a technical work group during the summer of 2011, provides an opportunity to understand the impacts of both individual strategies and the synergistic effects of different combinations of strategies. In Phase 2, Metro will use the metropolitan GreenSTEP model in conjunction with the Envision Tomorrow scenario planning tool. This approach assures compatibility with state modeling efforts throughout the process while enabling results to be 'mapped' to specific locations.

For each of the five sections above, two or more strategies are discussed in detail according to the following outline:

- Introduction
- Existing research findings
- Co-benefits and synergy with other strategies
- Considerations moving forward

In addition, this chapter includes call-out boxes that provide examples and results of applying a strategy; describe other tools or mechanisms that can enhance GHG emissions reductions; and frame other issues to be addressed moving forward.

An integrated approach

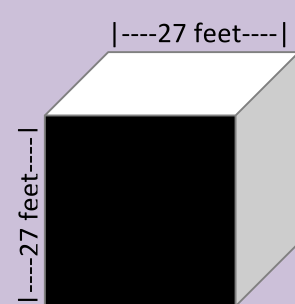
As previously stated, generation of transportation-related GHG emissions is the result of three main factors: vehicle technology, fuel characteristics and how much people drive (i.e. VMT). These three components can be compared to a three-legged stool, in recognition that a comprehensive transportation GHG emissions reduction strategy needs to include a mix of strategies.

Transportation system management and operations of the transportation network is a fourth factor that can reduce GHG emissions, thereby adding a fourth leg to the stool. This set of strategies focuses on improving the efficiency of the existing transportation system through advanced technologies, traffic incident management and traveler information to help people make better informed travel decisions, including travel mode, route and time of day. **Figure 7** shows this relationship.

Visualizing a Metric Ton of CO_2

Throughout the chapter, information for each strategy regarding GHG emissions or VMT reduction draws from a range of different research.

At times, the reduction is referred to as a percentage, but other times it is referred to in tons or metric tons. In the case of the latter, it is helpful to visualize the volume of CO_2. One metric ton of CO_2 is equivalent to 27 cubic feet.



The average US person emits a metric ton of CO_2 every two weeks.

For additional resources see:
http://www.epa.gov/cleanenergy/energy-resources/calculator.html

http://carbonquilt.org/visualiser

The Toolbox does not posit what mix of strategies should be implemented to meet the state GHG emissions reduction target. As the research shows, there is no silver bullet; and the range of potential GHG emissions reductions can vary based on how ambitiously a strategy is implemented, where it is implemented and the extent to which other supporting strategies are also implemented. The research identifies synergistic relationships among strategies and shows that all strategies can offer multiple potential community, economic and environmental benefits beyond GHG emissions reduction.

While a wide range of policy options are available to the region, selecting strategies will involve policy decisions that will need to consider the political, economic, environmental, equity, and community implications described in this report.

By informing a dialogue about the policy choices and tradeoffs that decision-makers will need to consider throughout the process, this report serves as a basis for determining the region's preferred approach to meeting the state targets. Ultimately, an integrated approach will be needed to confront the threat of global climate change through federal, state, regional and local actions that also advance the region's efforts to build livable, prosperous and equitable communities.

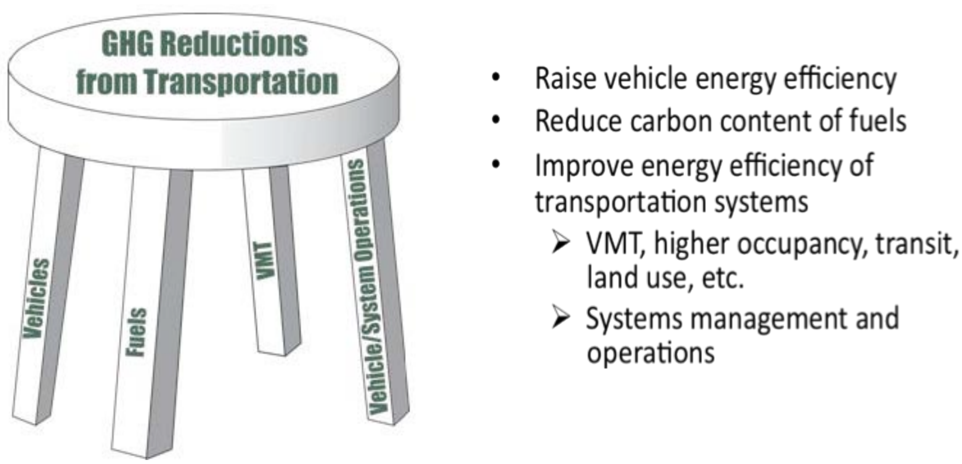


Figure 7. Greenhouse Gas transportation strategies -- the "four-legged stool"

Research Cautions and Caveats

Interpreting the VMT and GHG emissions reduction estimates in this report requires caution:

1. The research cited in this report uses varying methodologies and scales of analysis. For example, *Moving Cooler* results are based on a national level analysis, reflecting average conditions nationwide – some of which may be quite different than conditions in the Portland region. Other research cited is based on community-level or neighborhood-level analysis that do not always isolate for socio-economic and demographic characteristics that also influence how people travel.

2. Percentage reductions have been reported when possible to provide for more consistent comparison of strategies. However, the potential reduction(s) of a strategy or combinations of strategies are not additive. The potential reductions presented are, in many cases, quite variable in terms of their range, and the numbers reported are not always mutually exclusive in their effects. For example, the reported range of the GHG effects of density on VMT depend on the amount of land use mixing, design and the transit service provided.

3. There are many complicating factors that create the context for the effectiveness of a given strategy (e.g. land use mix, density, design etc.). The complexity of the interactions of land use, transportation, household demographic and socioeconomic characteristics and other factors often make it very difficult to isolate the impact of any individual strategy. For example, residents of more dense areas of cities tend to have smaller families, which can result in lower VMT due to the characteristics of the household, not the density.

Community Design Strategies

Community design refers to a collection of complementary strategies including a diverse mix of uses in an area or district (commercial, cultural, residential, entertainment), a range of housing and transportation choices for all income levels and generations, maintenance of a tight urban growth boundary, pedestrian and bicycle-friendly designs and connectivity, and reliable and frequent transit service.

The combined impact of these efforts has the potential for significant reductions in GHG emissions both directly and indirectly. The potential reductions highlighted below are not additive and vary depending on the combination of strategies implemented.

MIXED-USE DEVELOPMENT

People: the number of people or the development intensity of a given area is often used as a proxy for compact urban form, which directly affects increases in transit ridership

Places: by providing retail goods and services plus employment opportunities in close proximity, a diverse environment enhances the viability of walking, bicycling and use of transit

Physical form: the urban form and character of a community such as street grids, connected sidewalks and bike lanes, and the use of lighting and trees

5 to 25 percent

Reduction in VMT when doubling the amount of housing in a given area, with highest reductions achieved when accompanied by mixed uses, biking and walking connections and transit service

1 to 6 percent

Reduction in VMT for every mile closer to a transit station, an effect likely to occur within two miles of a rail station and three-quarters of a mile of a bus stop, depending on transit frequency

ACTIVE TRANSPORTATION AND COMPLETE STREETS

Pedestrian/bicycle connectivity: bicycling, walking and access to transit; complete streets are designed for all users

5 to 15 percent

Reduction in VMT in communities with good walking and bicycling conditions

PUBLIC TRANSIT SERVICE

Performance: a collection of strategies that can improve transit ridership includes increased frequency, system expansion, fares, and improved access to transit

1 to 8 percent

Reduction in GHG emissions when the transit network is expanded

CO-BENEFITS

Public health and safety benefits

- Increased physical activity from walking and biking, leading to reduced risk of obesity, diabetes, heart disease and premature death
- Enhanced public safety; reduced risk of traffic injuries and fatalities
- Improved air quality and fewer air toxics emissions, leading to reduced risk of asthma, lung disease and premature death

Environmental benefits

- Lower levels of pollution
- Less energy use
- Natural areas, farm and forest protection

Economic benefits

- Job opportunities
- Improved access to jobs, goods and services
- Consumer savings in home energy and transportation
- Municipal savings
- Leverage private investment, increased local tax revenues
- Increased property values
- Reduced fuel consumption, leading to less dependence on foreign oil
- Improved energy security

SYNERGY WITH OTHER STRATEGIES

- Parking pricing
- Tolls, fees, and insurance
- Public education and marketing
- Individualized marketing
- Employer-based commuter programs
- Traffic management
- Fleet mix and turnover

IMPLEMENTATION

While mixed-use developments can reduce public costs and increase access to social, economic and employment opportunities, they can be more complicated and have significantly higher upfront costs than traditional single-use development. Public transit service can also have significant costs when considered on its own while bicycle and pedestrian infrastructure is relatively less inexpensive. However, given the cost effectiveness in the long term, it is integral to use incentives to reduce upfront costs and simplify the process. The resulting increase in economic activity in these areas is good for the local economy and can be reinvested in on-site amenities and expanding transportation choices.

Mixed-use Development in Centers and Transit Corridors

A COMMUNITY DESIGN STRATEGY

Mixed-use development is the use of a building, a set of buildings, a district or a neighborhood for more than one purpose. Often located in existing urban areas or as part of a new urban center or corridor, mixed-use development provides a full complement of jobs, affordable housing options, services, civic uses, and community spaces. It is sometimes called "smart growth," "compact" mixed-use development, or transit- and pedestrian-oriented development.

Mixed-use development is comprised of a group of strategies including higher residential and employment densities, a diverse mix of uses (commercial, cultural, residential, entertainment), a mix of affordable housing and transportation choices, maintaining a tight urban growth boundary, pedestrian and bicycle friendly design, and reliable and frequent transit service.

Mixed-use development is connected to local and regional destinations via a dense network of pedestrian and bicycle facilities and transit options, connecting people to social, economic and employment opportunities. Housing types are diverse, potentially ranging from studio apartments to detached single-family residences, thereby providing housing opportunities for a range of incomes and generations.

Mixed-use developments often result in residential buildings with street front commercial space – typically called "vertical mixed use." However, mixed-use development can also be integrated horizontally across several parcels, a corridor, a district or a neighborhood. When jobs, housing, and commercial activities are located close together, an individual's transportation options increase, and the distance the individual needs to travel to meet their daily needs is reduced. Retailers have the assurance that they will always have customers living right above and around them, while residents have the benefit of being able to walk or bike a short distance to goods and services.

Research has shown that mixed-use development can produce diverse and vibrant communities that can have the added benefit of reducing traffic and related transportation costs. By integrating different uses such as homes, offices, and shopping, many daily trips can be eliminated or reduced in length. Zoning was established in the 1920's to separate different uses whose proximity was undesirable, such as separating factories from residences. But today most workplaces are clean and quiet and can be built closer to homes without adverse effects. Many employers also find that locating workplaces near shops, banks, dry cleaners, and restaurants can save their employees time.

With the adoption of the 2040 Growth Concept in 1995, the region committed to a holistic approach that targets future growth and development in designated regional and town centers, transit corridors and employment areas - within walking distance from adjacent neighborhoods and that provide access to local goods and services and can be more effectively served by transit. The aim is to reduce how much people need to drive and how far they need to travel to meet their daily needs. This can, in turn, help reduce household transportation costs, time spent commuting to work and GHG emissions, as well as support other desired outcomes.

The Five P's of mixed-use development

As part of its strategic planning process, Metro's Transit Oriented Development Program explains the relationship of development patterns to travel behavior by analyzing the Five P's of transit oriented development.

People: Intensity of development and/or population in an area

Places: Mix of uses, especially neighborhood serving goods and services

Physical Form*: The built environment as experienced and navigated by the pedestrian

Pedestrian/Bicycle Connectivity: Access to sidewalks and bikeways

Performance: High quality, frequent bus and rail service

People, Places and Physical Form are addressed in this strategy section.

*People, Places and Physical Form are traditionally expressed as Three D's: Density, Diversity and Design.

Existing research findings

Greenhouse gas emissions reduction potential

People, a factor measured by the number of people or the development intensity of a given area, is often used as a proxy for compact urban form. The impact of 'People' on travel behavior and related GHG emissions is significant.

The direct impact of 'People' on VMT and GHG emissions has been documented. A recent national study concluded that, on average, doubling residential density is associated with VMT reductions that range conservatively from five to 12 percent, and perhaps by as much as 25 percent if coupled with higher employment concentrations, significant public transit improvements, mixed uses and other supportive demand management strategies (Transportation Research Board, *Driving and the Built Environment* 2009).

Nearly every study of transit ridership has provided evidence that 'People' is its primary determinant. In the Portland region, a study found that 93 percent of the variation of transit demand is explained by employment and housing density, even after controlling for 40 other socio-demographic and land use variables (Nelson\Nygaard 1995).

Other similar statistical research that focused on the San Francisco Bay Area has found that increases in residential and employment density around transit stations can have a positive influence on the number of commute transit trips. A study of 129 San Francisco Bay Area rail stations found that the commute mode split was 24 percent in neighborhoods with a housing density of ten units per gross acre. This figure jumps to 43 percent in station areas with 20 units per acre and 67 percent in station areas with 40 units per acre (Cervero 2004).

Case Study: Potential CO_2 Reductions in Transit Zones

A recent study by the Center for Transit Oriented Development on behalf of the Chicago region developed national transit zone types based on characteristics of the built environment such as density, block size and transit access. It found that areas with characteristics similar to Gresham and Hillsboro regional centers produce 31 percent fewer auto-related GHG emissions than the average neighborhood in the 52 metropolitan areas sampled. Households within compact mixed-use neighborhoods like Nob Hill in Northwest Portland generated 60 percent less GHG emissions. Below is a table showing transit zone types, their performance and comparable Metro area design types.

National Transit Zone Type	Average Density (households per acre)	Average Walkable Transit Access Options	Average CO_2 per household (metric tons)	Reduction from national average* (percent)	Similar Metro Region Centers
Highest	62	98	1.46	78%	City Center (Pearl District)
High	30	26	2.66	60%	**None****
Medium-High	9	13	4.61	31%	Gresham, Hillsboro, Lake Oswego
Medium	4	6	6.06	10%	Beaverton, Milwaukie, Oregon City
Low	4	2	6.51	3%	Tigard, Tualatin, Forest Grove
Lowest	1	1	8.81	-31%	Wilsonville, Happy Valley

*6.7 average household CO_2 in 52 sampled metropolitan regions with transit comparable area in the region

**Nob Hill-Northwest Portland is the most similar

Employment density, workers' travel patterns, and employment land use may be just as important as residential density near transit, residents' travel patterns, and residential land use (Kolko 2011). In terms of employment density, significant commuter modal shifts to transit occur as worksites reach 50-75 employees per gross acre, suggesting employment densities and workplace proximity to transit are important for achieving GHG emissions reductions and other transportation goals (Frank and Pivo 1994).

More recent research concluded workplace proximity to transit should matter more for transit ridership than residential proximity to transit because "unlike the home end of the trip, where there are many options for accessing transit, generally, walking is the only available option at the work end" (Barnes 2005). Accordingly, employment densities at trip destinations affect ridership more than residential densities at trip origins (Arrington and Cervero, 2008; Transportation Research Board 2009). Furthermore, achieving high employment densities can be more feasible politically than achieving high residential densities (Barnes 2005).

Places refers to a mix of land uses. By providing retail goods and services, residential and employment opportunities in proximity, people do not have to travel as far, and walking, bicycling and transit become more convenient and viable travel options. 'Places' has been shown to impact travel behavior because areas with a greater mix of uses often result in less driving. The evidence of the relationship, however, is more variable than that shown for 'People.' This is largely due to the difficulty in objectively defining or quantifying a mixed-use environment.

Two studies showed that a 100 percent increase in land use mix can result in an average VMT decrease in a range from two to 5 percent (Ewing and Cervero 2010 and Lawrence Frank 2011). The studies controlled for other variables (e.g. income, density, transit availability) and used disaggregated household data (Transportation Research Board, *Driving and the Built Environment* 2009).

Perhaps the mixed-use data most pertinent to the Portland region is the 1994 Household Travel Behavior Survey. Summarized in **Table 2**, this often cited survey sampled 4,451 households from across the region and reported on nearly 68,000 trips (completing more than 120,000 activities) over the course of two days. This sample was stratified based on neighborhood mix of uses and relative access to high-quality transit service.

Respondents in mixed-use neighborhoods with access to good transit service reported daily VMT of 9.80 per capita. Single-use neighborhoods with good transit averaged approximately 35 percent more vehicle miles, or 13.28 per capita. Although this latter figure was higher, thereby reflecting the connection between land use diversity to travel behavior, it is still significantly lower than the remainder of the region, which averaged 21.79 VMT per capita.

Table 2. 1994 Regional Travel Behavior Survey Results

Land-Use Type	Auto	Walk	Transit	Bike	Other	Vehicle Miles per capita	Auto ownership per household
Good transit and mixed-use in Multnomah County	58.1%	27.0%	11.5%	1.9%	1.5%	9.80	0.93
Good transit only in Multnomah County	74.4%	15.2%	7.9%	1.4%	1.1%	13.28	1.50
Remainder of Multnomah County	81.5%	9.7%	3.5%	1.6%	3.7%	17.34	1.74
Remainder of region	87.3%	6.1%	1.2%	0.8%	4.0%	21.79	1.93

Source: Metro Household Travel Behavior Survey (1994).

While the results in Table 2 are likely influenced by socio-economic and demographic characteristics of the households in the study, the research also demonstrates the synergy between public transit, mixed-use development and density in the region. Areas with good transit and mixed-use development have 58 percent auto use. By contrast, areas with good transit but without mixed-use development have more auto use and suburban areas with poor transit and less mixed-use development have as much as 87 percent auto use.

A new household survey is underway in the region that will provide updated information about the synergy between these strategies. The survey may find that these differences have become more pronounced since the region has added more mixed-use development, 37 miles of MAX light rail (Westside, Airport, Interstate, I-205), more frequent bus service in major travel corridors and substantial pedestrian and bicycle infrastructure throughout the region.

Housing and Transportation Affordability

Housing and transportation affordability is essential to addressing Metro's six desired outcomes. National research by the Brookings Institute (Center for Transit Oriented Development and Center for Neighborhood Technology 2006) has found that residential density and household income drive auto ownership, auto use and transit ridership. Low income households are more likely to take public transit if available as an option. The research also found that places with access to services, walkable destinations, extensive and frequent transit, access to jobs, and density have lower household transportation costs.

More recent local research shows lower income families in the Portland region are moving to areas that are often farther from their jobs, and are not as well-served by transit and other services, due in part to lower housing prices in these areas (Coalition for A Livable Future 2007). This displacement trend, if unaddressed, will likely lead to greater vehicle dependence and fuel consumption by families of modest means. Furthermore, lower income families are more likely to drive older, less fuel efficient vehicles, resulting in higher fuel consumption and transportation costs for those who can least afford it. Rising gas prices compounds this issue further adversely affecting vulnerable families in auto-dependent neighborhoods by placing more stress on family budgets.

As the region grows, demand for new housing of all types will increase. Affordable housing choices need to be integrated within the broader set of mixed-use development strategies to provide a range of housing and transportation options for all residents in the region. The two approaches are synergistic because, when implemented together, they increase access to jobs, education, essential services, transportation choices, public spaces, and parks. This in turn can help save families money and lead to more efficient land use patterns and transportation systems. The improved efficiencies will be passed on to households, businesses and governmental entities as cost savings.

Creating neighborhoods with housing and transportation affordability requires multiple and targeted strategies and coordination within and across government agencies and the private sector. Certain policies and techniques can ensure that affordable housing choices are part of any new or infill development:

- Tax increment financing
- Density bonuses
- Transfer of development rights
- Exemption from impact fees
- Allow accessory dwelling units
- Create small lots and small lot districts
- Implement performance zoning
- Adaptive reuse
- Planned unit development
- Cluster subdivisions

Physical Form is the urban form and character of a community or neighborhood. As with ‘Places,’ understanding the effectiveness of ‘Physical Form’ is subjective because the relationship to VMT and GHG emissions depends on the variables chosen to evaluate the physical design and characteristics of an area.

The density and configuration of street blocks dictates urban form and connectivity, both of which impact travel behavior. Street patterns and block size are commonly used as building blocks for neighborhood design. Ewing and Cervero (2010) find that intersection density and street connectivity has the second greatest impact on travel activity of all land use factors analyzed. The report concluded that increasing intersection of street density by 10 percent reduces vehicle travel by 1.2 percent. A study sponsored by the Puget Sound Regional Council also found that per household VMT declines with increased street connectivity. It concluded that a 10 percent increase in intersection density reduces VMT by about 0.5 percent (Frank et al 2005).

Greater street connectivity, a result of a traditional urban grid network, can also reduce walking distances, which impacts travel behavior. For every mile closer to a transit station, VMT decreases between 1.3 percent and 5.8 percent. Reductions are most likely to occur within two miles of a rail station and about three-quarters of a mile of a bus stop, depending on the frequency of transit service (California Air Resources Board 2010). Households very close to transit lines produce about one-quarter of the emissions of those households that are located further away. Other research showed that design factors, such as block size when combined with housing density provide an even stronger influence on the potential for increasing commute transit ridership than housing density by itself (Cervero 2004). This can translate into significant VMT and GHG reductions.

It is important to note that many of these studies do not necessarily control for the overall street design, e.g. travel lane widths, sidewalks, bike lanes, lighting and the use of trees and pedestrian furniture. Some research argues that these elements contribute to the VMT reductions (Upstream Public Health 2009). In fact, the impact of improved design on VMT ranges from a 3 to 21 percent reduction depending on what other community design policies are implemented (CAPCOA 2010). Good design can help promote walking and biking as a primary mode of travel by making the network safe, interesting, and easy to use.

Combined Impact

Given that the ‘People,’ ‘Places,’ and ‘Physical Form’ are highly correlated (e.g. higher densities, a mix of uses and dense block patterns tend to occur in the same place), it is difficult to discuss the impact of their individual contributions without considering their combined impact. One study concluded that doubling density in combination with other policies, including those that affect land-use diversity, neighborhood design, access to transit, and accessibility, could have significant impacts on travel behavior – such as reductions in VMT on the order of 25 to 30 percent (National Association of Home Builders 2010). A focused compact growth strategy around transit in a region such as Chicago could reduce future VMT-related GHG emissions by 36 percent (Center for Neighborhood Technology 2010).

Perhaps the most comprehensive national-scale research completed to date comes from a report to Congress (US DOT 2010) that synthesized existing national research and performed original research to quantify the range of potential GHG emissions reductions from land use strategies. The report relies on the middle ranges of three reports to estimate that land use strategies can reduce transportation-related GHG emissions by 1 to 4 percent by 2030 and 3 to 8 percent by 2050 (Transportation Research Board 2009; Cambridge Systematics 2009; and Ewing et al 2007). The Moving Cooler study assumes that 43 to 90 percent of new development would occur in areas of roughly greater than five residential units per acre (Cambridge Systematics 2009).

Case Study: Sacramento Council of Governments (SACOG) Scenarios

The Sacramento region evaluated alternative transportation and land-use growth scenarios through 2050 and calculated the costs for both the Base Case Scenario and the Preferred Blueprint Scenario. The adopted Preferred Blueprint Scenario features infill development and transportation investments in order to reduce GHG emissions and lower infrastructure costs. VMT is estimated to decrease between six percent and ten percent per capita under the Preferred Blueprint due to locating new homes and destinations closer together and expanding the range of transportation choices.

Sacramento's smart growth plan is also projected to reduce emissions by 7.2 million metric tons of carbon dioxide – a 14 percent reduction in CO_2 from the business-as-usual forecast. This scenario results in a *net* economic benefit of $198 to $341 per ton CO_2 saved through $9 billion dollars on infrastructure and consumer fuel savings. Even if upfront costs amounted to $1 billion, the net benefits would still range from $70 to $211 per ton CO_2 saved.

A number of studies across the country have measured the combined impact of the P's of the built environment on travel behavior at the local or neighborhood level. Since much of this research compared rates of VMT in communities marked by different urban forms, the findings show that transportation-related GHG emissions can be highly varied.

A case study of two recently constructed neighborhoods in North Carolina found significant differences in household VMT between mixed-use and non-mixed-use developments (Khattak and Daniel Rodriguez 2005). The study compared a typical suburban, single-use neighborhood with a neo-traditional one that was centered on a mixed-use commercial center. The findings indicated that residents of the mixed-use development made approximately the same number of trips, but traveled 14.7 fewer miles per household per day.

In a more urban setting, residents of Atlantic Station, a major neo-traditional brownfield redevelopment in Midtown Atlanta, demonstrated an average VMT 59 percent lower than the average city resident. VMT for employees in the development were 36 percent lower (Center for Clean Air Policy 2009).

Changing multiple land use variables at the same time can produce larger effects because of synergy among different characteristics. One study compared predicted VMT for sample households in 114 urban areas (Bento 2005). The study included 'moving' sample households from a city with characteristics of Atlanta to a city with characteristics of Boston. It found that predicted VMT in Boston is 25 percent lower than in Atlanta, suggesting that the combined effect of changing multiple land use variables will be larger than the effect of changing density alone.

Cost-effectiveness and feasibility of implementation

There is a growing demand for walkable communities close to transit, services, shopping and other activities, with associated challenges and opportunities for their implementation. Studies suggest there is a growing consumer demand for walkable communities with proximity and access to local goods and services, and public transit that will impact the real estate market over the next two decades (Center for Clean Air Policy 2009). The growing demand is in part due to demographic changes and shifting market preferences (Jonathan Rose Companies 2011), and areas with this type of development pattern have seen a less pronounced decline in housing values during the recent economic recession (Center for Clean Air Policy 2009).

Developers have increasingly proposed mixed-use developments to adapt projects to infill locations, gain access to greater densities, respond to changing consumer demands, and capitalize on the synergies created by the integration of complementary uses (Rabianski 2009). These findings suggest there is latent opportunity for significant private investment and potential profits in developing mixed-use projects in centers and along corridors that are served by public transit in the Portland region.

However, mixed-use development is much more complex and complicated than single-use development. Mixed-use projects present developers with increased complexity and risk at every stage of the development process, including

Mixed-Use Development Incentives

The use of incentives can encourage compact, mixed-use development. Incentives are most effective when used in combination with other tools such as strategic management of the urban growth boundary, flexible development codes, parking management and pricing. In addition, local design and zoning codes must be altered to remove any potential barriers to using these incentives.

Effective incentives influence the final cost and financial return of a development project through one or more of the following components:

- Pricing (rent or sales price) that is achievable in a district
- Cost of construction
- Level of financial risk

Examples of incentives include:

<u>Direct incentives</u>

- Grants
- Tax abatement
- System development charges reflective of reduced impacts

<u>Indirect incentives</u>

- Infrastructure investments
- Investments in community amenities
- Flexible parking or landscaping standards
- Time certainty in permitting

See Metro's Community Investment Toolkit for details about incentives.

http://www.oregonmetro.gov/index.cfm/go/by.web/id=28446 planning, land acquisition and entitlement, design, financing, construction, or operation the project (Herndon and Drummond 2011). A review of the literature covering factors that influence the success of mixed-use development found that financial success depends on being able to maximize and mix the uses in a way that responds to market conditions, opportunities and economics, while being compatible with its neighbors and the overall community (Rabianski and Clements, 2007).

Although the 2040 Growth Concept has helped leverage significant changes to local comprehensive plans and development codes in support of mixed-use development, the cost and complexity of this style of development often renders it infeasible in all but the strongest real estate submarkets. Elevators, underground parking and structural components of multi- story, mixed-use buildings can significantly increase design and construction costs. Redeveloping older buildings to accommodate new uses requires upgrading them to meet current codes and standards, which is also costly. In addition, these cost constraints, in combination with limited regional policy mechanisms, can create barriers to addressing housing affordability.

Attracting enough successful businesses to reinvigorate downtowns and main streets is an added challenge in this age of internet shopping and big box retail. In a commercial district that is not a known "destination" that draws clientele from a wide area, it's a challenge for many small businesses to pay the higher rents associated with newly constructed or renovated buildings. This is particularly true if the surrounding neighborhoods are not sufficiently dense to create a solid base of local customers. As a result of these barriers and chicken-and-egg dilemmas, many downtowns and main streets throughout the Portland region are only just beginning to turn the corner and have not yet developed to their full potential.

Leverage private investment. The Center for Transit Oriented Development estimates that "$1 in public transit investment can leverage up to $31 in private investment." Public investments in transit and smart growth policies in Little Rock, Arkansas, Tampa, Florida, Portland, Oregon, Atlanta, Georgia, and Arlington, Virginia have helped leverage a ten- to thirty-fold increases in private investments. In addition, tax revenues have increased significantly and, in some cases, have far outweighed the initial upfront costs (Center for Clean Air Policy 2009). Metro's Transit Oriented Development Program has invested $30 million that has helped leverage $318 million in private real estate investment across the Portland region. In addition, such leveraging helps reduce the risk and cost to developers that come from the complexity of mixing land uses, the increased planning and construction costs, and the longer development horizon.

Lower infrastructure costs. The Center for Clean Air Policy documented notably lower infrastructure costs, by 25 percent or more, for serving more compact growth patterns as opposed to lower-density, auto-dependent development patterns (Center for Clean Air Policy 2009). Infrastructure costs are lower due to the reduced size of the area being served and reduced use of existing infrastructure. Other research has shown that low-density development requires more fire and police stations, as well as more vehicles and safety equipment, per capita to adequately respond to emergencies. Similarly water and sewer systems, schools, libraries, parks and hospitals also require upfront infrastructure expenditures that are significantly more expensive in low-density areas. Public services are said to be more expensive due to the greater distribution of these activities (Transit Cooperative Research Program 2000).

Despite impressive long-term returns for compact, mixed-use development in centers and corridors, this type of development can have significantly higher upfront costs associated with redevelopment. However, given the cost-effectiveness of this approach when compared to alternative development patterns, it is essential to use incentives and other measures to reduce risks and upfront costs that make it easier to build infill and mixed-use projects. The resulting increase in economic activity in these areas is good for the local economy and can be reinvested in on-site amenities and expanding transportation choices.

Political challenges. Political feasibility is another important factor in determining which policy and investment options to pursue when implementing mixed-use development. Several studies mention the need for more public support to gain the political momentum necessary for new policies or investments. Some view the reemergence of mixed land uses as a threat to their community and believe that "greater density in suburban areas threatens [their] social and economic attractiveness." (Kotkin 2010)

All of these challenges and opportunities need to be considered when exploring the potential of different policies and investments to affect VMT and GHG emissions. Thus, the full GHG emissions reduction potential of this strategy is constrained to some degree by local market conditions, financial feasibility, lending practices and public acceptance.

Building energy consumption co-benefits

When factoring in building performance, households in moderate density neighborhoods (7.8-15.6 households per acre) generate half the building energy emissions of households in areas of very low density (1 household per 16 acres) (Jonathan Rose Companies 2011). This is due primarily to the inherent energy efficiency of multi-family building types with shared walls and fewer exposed surface areas.

Similarly, a study of the environmental impacts of housing development practices in Oregon found that multifamily housing had roughly half the climate impacts of an average medium-sized home (roughly 2,200 square feet). This is because the every-day use of the home (cooking, heating, cooling, etc.) contributes about 86 percent of the total lifecycle GHG impact of housing from construction to demolition. In addition, home size alone has an environmental impact. For example, a small home (1,149 square feet) provides a 40 percent reduction in GHG emissions compared to a medium-sized home (2,262 square feet) due to energy use. Further, a 4-unit multifamily building provides a 14 percent reduction in GHG emissions compared to a single-family home of the same size (2,262 square feet). An eight-unit building with a unit size of 1,149 square feet provides even greater benefits with a 46 percent reduction in GHG emissions compared to a medium-sized single family home (Oregon DEQ 2010).

Caveats on research

One caveat of this research is that the full GHG emissions reduction of mixed-use development appears to depend on the "sum of the parts" or the presence of all or most of these variables. The most reliable studies estimate that doubling residential density across a metropolitan area may lower household VMT by 5 to 12 percent, and perhaps by as much as 25 percent if coupled with higher employment concentrations, significant public transit improvements, mixed uses and other supportive demand management strategies.

Two other caveats about research methodology are also noted. First, some of the studies did not carefully control for some of the key socioeconomic characteristics that impact travel behavior such as income, household size and auto ownership. Second, rarely did studies account for self-selection. That is, residents and employees of compact, mixed-use neighborhoods may have chosen to live/work there because of their access to alternative transportation. Thus, one cannot necessarily attribute their travel behavior completely to the built environment if they were already predisposed to biking, walking, or riding transit.

Co-benefits and synergy with other strategies

Co-benefits

Beyond reducing GHG emissions, the compact mixed-use development strategy has the potential to provide other important benefits to a community.

Public health and safety benefits:

- Increased physical activity from walking and biking, leading to reduced risk of obesity, diabetes heart disease and premature death
- Enhanced public safety; reduced risk of traffic injuries and fatalities
  - More "eyes on the street"
  - Quicker emergency services response
- Improved air quality and fewer air toxics emissions, leading to reduced risk of asthma lung disease and premature death

Economic benefits:

- Job opportunities
- Increased access to jobs, goods and services
- Consumer savings from reduced home energy and transportation costs
- Leverage private investment, increasing local tax revenues
- Increased property values
- Improved energy security
- Municipal savings
- Increased cost effectiveness of transit investment through improved ridership

Environmental benefits:

- Lower levels of pollution
- Less energy use
- Natural areas, farm and forest protection
  - Added capacity to absorb CO2 by preserved forest canopy

Urban Growth Boundary

The fact that all cities in Oregon maintain an urban growth boundary (UGB) has made the state a leader compared to most of the U.S. in the advancement of mixed-use compact urban form, which helps to reduce average VMT. Continued management of land supply through the use of the UGB will be an important strategy for encouraging a compact urban form for the region and minimizing the displacement of residential growth to neighboring cities.

UGB expansions can only be made after demonstrating that forecasted growth cannot reasonably be accommodated within the existing UGB. According to Metro's *Land Use and Investment Scenarios* report (Metro 2008), past scenario evaluations indicate that modest variations in where and how much the UGB is expanded are not likely to cause substantial changes in the average commute distance for the region. This is because household and job growth in expansion areas is a small share of total growth.

Past scenario analyses do, however, indicate that a tight UGB policy may result in small decreases in average commute distance for the seven-county region. These small decreases can have a large cumulative effect, particularly if complementary strategies, such as investments in existing urban areas, are pursued.

More importantly, the way in which UGB expansion areas are designed and developed will influence the travel behavior of people who live or work in the expansion area. Likewise, the efficiency of development in expansion areas will factor into the need for future UGB expansions. As new urban areas are planned and developed, careful attention to the five P's will be essential.

Synergies with other strategies

Synergy exists when a combination of two or more strategies enhances the potential GHG emissions reductions from an individual strategy. Mixed-use development in centers and corridors is synergistic with several other strategies including:

- Active transportation and complete streets
- Public transit service
- Parking pricing
- Tolls, fees, and insurance
- Public education and marketing
- Individualized marketing
- Employer-based commuter programs
- Traffic management
- Fleet mix and turnover

Considerations moving forward

Transportation and land use are interdependent. The research shows there is clearly a relationship, if not causation, between urban form and transportation-related GHG emissions by way of VMT. Decisions on the location and density of housing, retail, offices and commercial services impact travel behavior to these destinations.

A focus on mixed-use development in centers and corridors has strong potential to reduce overall GHG emissions in the long-term. At the regional level, it appears that creating pedestrian and bicycle friendly communities with access to parks and open space, increasing densities, introducing neighborhood-oriented retail goods and services, locating job opportunities closer to where people live and enhancing street connectivity could reduce VMT by up to 25 percent. The reductions largely come from reduced trip distances (because destinations are located closer together) and increased walking, bicycling and use of transit. Thus, implementation of a mixed-use development strategy will occur through public-private partnerships and at multiple scales, ranging from state and regional policies and funding to local development codes and incentives.

Mixed-use development is appropriate in downtowns, neighborhood-oriented centers, transit nodes, main streets, and some community commercial centers. While there is evidence of a growing demand for this type of development, implementation of this strategy should be based on carefully-crafted policies that seek to minimize developer risk and higher upfront costs, increase affordability, minimize displacement and address livability concerns raised by existing residents and neighborhoods.

It will be important to ensure there are tools in place to protect existing, and encourage new, affordable housing as new areas are planned and existing areas redeveloped. As our communities become more diverse, it will also be important to ensure that these investments are relevant to multiple demographics and benefit all income levels equitably.

Continued management of the region's urban growth boundary (UGB) will also be an important strategy for encouraging a compact urban form for the region and minimizing the displacement of residential growth to neighboring cities. If residential growth is displaced to neighboring communities outside of the UGB, but those residents continue to work inside the UGB, localized GHG reduction benefits could be negated. Perhaps more importantly, the way in which UGB expansion areas are designed and developed will influence the travel behavior of people who live or work in an expansion area. Likewise, the efficiency of development in expansion areas will factor into the need for future UGB expansions.

Active transportation, also referred to as "non-motorized transportation," means bicycling, walking and access to transit. 'Complete streets' are streets designed and operated with all users in mind including people driving cars, riding bikes, using a mobility device, walking or riding transit.

Integrating on-street pedestrian and bicycle connections with off-street biking and walking trails comprises the strategy analyzed in this section. For several years, the Portland region has employed this strategy as a key component to reduce auto trips and to help support the region's 2040 Growth Concept land use vision of compact mixed-use development in centers and corridors. This strategy must be considered in conjunction with compact mixed-use development, higher residential and employment densities, affordable housing, a mix of land uses, regional growth management (e.g. urban growth boundary), and public transportation.

The active transportation and complete streets strategy has been pursued at the regional and local levels. While the region is recognized as a national leader in active transportation, the region's investment in bicycling and walking facilities has been piecemeal and opportunistic due to a lack of dedicated funding and a regionally-agreed upon implementation strategy. This has resulted in a less-than-seamless network that limits opportunities to safely walk or bike in many areas of the region.

The Five P's of mixed-use development

As part of its strategic planning process, Metro's Transit Oriented Development Program explains the relationship of development patterns to travel behavior by analyzing the Five P's of transit oriented development.

People: Intensity of development and/or population in an area

Places: Mix of uses, especially neighborhood serving goods and services

Physical Form: The built environment as experienced and navigated by the pedestrian

Pedestrian/Bicycle Connectivity: Access to sidewalks and bikeways

Performance: High quality, frequent bus and rail service

Pedestrian/Bicycle Connectivity is addressed in this strategy section.

Existing research findings

GHG emissions reduction potential

A range of GHG emissions reduction potential has been revealed in national research on active transportation and complete streets. *Moving Cooler* found that pedestrian and bicycle infrastructure policies applied nationally would result in a cumulative 0.2 to 0.5 percent reduction in baseline GHG emissions by the year 2050 (Cambridge Systematics 2009). This research does not take into account the combined reduction benefits that can be achieved by implementing this strategy with changes to land use, expanded transit service, marketing, and incentive programs that are described elsewhere in this document. A report by the California Air Pollution Control Officers Association found that when pedestrian accommodations in urban or suburban neighborhoods exist within the project site and connect to off-site destinations, VMT reduction is estimated to reach 2 percent (CAPCOA, 2010).

Other research has estimated that bicycling and walking already reduce GHG emissions as much as 12 million metric tons of CO_2 per year (the equivalent of over two million cars annually). As well, the potential exists, for future GHG reductions from increased walking and biking between 33 and 91 million metric tons of CO_2 per year (Center for Clean Air Policy 2009).

National and local research has found that active transportation and complete streets strategies can replace some auto trips, especially short ones. Half of all trips in the U.S. are less than three miles in length (National Household Travel Survey 2009), which is a distance well-suited to bicycling. Portland State University researchers found that for trips less than three miles, the bicycle is time competitive with the automobile (Dill, Gliebe 2008). Additionally, they found that a well-connected street network is important to cyclists, both for minimizing travel distances and allowing for an efficient network of low-traffic streets and bicycle boulevards.

A King County, Washington study found that residents in the most interconnected areas of the county travel 26 percent fewer vehicle miles per day than those that live in the most sprawling areas of the county (Frank, Sallis, et al. 2005); a national study found five to 15 percent fewer VMT in communities with good walking and bicycling conditions (Rails to Trails Conservancy 2007).

Case Study: The Effects of Bicycle Investments in Portland, Oregon

The City of Portland is one of the best examples in the United States of how a city's investment in completing the bicycling network has dramatically increased the bicycling mode share and thereby reduced VMT (Pucher, Dill, et al.).

- Between 1991 and 2010 the City of Portland quadrupled the size of its bikeway network from 79 to 324 miles. City bike counts show that during the same time period the amount of bicycle traffic crossing four Willamette River bridges grew six times from 2,850 to 17,576.
- The share of city workers commuting by bicycle rose from 1.1 percent in 1990 to six percent in 2008. The number of all workers commuting by bicycle increased 608 percent from 1990 to 2008, while the number of workers increased only 36 percent.
- One study indicates that given the low baseline level in the early 1990s and the large increase in bicycle counts through 2010, it is fair to assume that there is a causal relationship between investments and the observed exponential growth in bicycling (Gotschi 2011).

Cost-effectiveness and feasibility of implementation

Constructing pedestrian and bicycle infrastructure has a relatively low cost of implementation. While more expensive than some system and demand management strategies, it is much less expensive than other capital strategies, such as public transit. Research on implementation costs has found a range of \$80-\$210 per ton of CO_2 emissions reduced compared to \$255 per ton to expand public transportation options and \$1,300 per ton to decrease transit fares (Cambridge Systematics 2011).

Bike and pedestrian infrastructure provide significant economic benefits. An analysis of Portland's Rails-to-Trails investment in bike infrastructure estimates a reduction of 0.73 million metric tons of carbon dioxide ($MMTCO_2$) by 2040 with a net economic benefit of \$1.2 billion (\$1,664 per ton CO_2 reduced) from fuel and health care cost savings. These savings do not account for road infrastructure savings, congestion relief, or increases in real estate values, which have been associated with investments in bicycle and pedestrian networks (Center for Clean Air Policy 2009).

Caveats on research

The research cited in this section uses varying methodologies and scales of analysis. For example, *Moving Cooler* results are based on a national level analysis, reflecting average conditions nationwide. Interpreting GHG emissions reduction estimates and cost effectiveness requires caution; there are many complicating factors that create the context for the effectiveness of a given strategy (e.g. land use, density, etc.). The complexity of the interactions of land use, transportation and other factors make it very difficult to isolate the impact of any individual strategy.

Additionally, no studies have been conducted that provide evidence of the impact this strategy has on reducing GHG emissions *directly*. But, an increase in bicycling and walking trips (including those that lead to transit trips) can be translated into reductions of VMT, which translates to reductions of GHG emissions.

Co-benefits and synergy with other strategies

Co-benefits

Beyond reducing GHG emissions, the active transportation and complete streets strategy has the potential to provide other important benefits to a community.

Public health and safety benefits:

- Increased physical activity from walking and biking, leading to reduced risk of obesity, diabetes and heart disease and premature death
- Enhanced public safety; reduced risk of traffic injuries and fatalities

- Improved air quality and fewer air toxics emissions, leading to reduced risk of asthma and lung disease and premature death

Environmental benefits:

- Lower levels of pollution
- Less energy use

Economic benefits:

- Job opportunities
- Increased access to goods and services
- Increased property values and leverage private investments, increasing local tax revenues
- Consumer savings
- Municipal savings
- Improved energy security
- Increased cost effectiveness of transit investments

Other local, national and international studies have found that pedestrian and bicycle infrastructure projects also:

- Result in 11-14 jobs per $1 million of spending in Baltimore, MD (Garrett-Peltier 2010)
- Provide $1.4 billion annually in nationwide economic activity in retail and tourism, on top of increased real estate values, time and health care cost savings (Gotschi 2009)
- Avert $81 million annually in healthcare costs due to physical activity opportunities provided by the Portland region's bicycle and pedestrian trails (Beil 2011)
- Increase by 85 percent the likelihood that adolescents who bike 3-4 days a week will be normal-weight adults (Blumenthal 2010)
- Increase by 15-20 percent the likelihood that people located in urban neighborhoods who report having sidewalks get at least 30 minutes of moderate-to-vigorous activity at least five days a week (Sallis, et al. 2009)
- Provide greater health benefits than focusing GHG reduction efforts solely on lower-emission vehicles in London and Delhi (Woodcock, Edwards, et al. 2009)

Synergies with other strategies

Synergy exists when a combination of two or more strategies enhances the potential GHG emissions reduction from an individual strategy. Active transportation and complete streets is synergistic with several other strategies including:

- Mixed-use development in centers and transit corridors
- Public transit service
- Parking pricing
- Public education and marketing

- Individualized marketing
- Employer-based commuter programs

The *Moving Cooler* report analyzed various bundles of strategies including one that aimed to capture the synergies between land use, transit, walking and bicycling. These strategies combine to reduce the number and length of trips taken by single occupancy vehicles. This bundle would yield a nine to 15 percent reduction in GHG emissions by 2050 (Cambridge Systematics 2009).

The Portland region has found synergy between the active transportation strategy and public education programs and employer outreach such as individualized marketing programs, Sunday Parkways (street closure events creating a temporary car-free route through a neighborhood), transportation management associations, biking and walking maps, etc. These programs make it easier to use walking and biking infrastructure improvements. They have not been evaluated extensively for their impact on GHG emission reductions, but the few studies available suggest that they have an impact on increasing walking and biking (Handy, Tai, Boarnet 2010).

Public transportation complements walking and biking and is generally accepted as a synergistic GHG reduction strategy (Cambridge Systematics 2011). By effectively linking walking and biking with public transit, the reach of all three modes allows longer trips to be made without having to drive.

Considerations moving forward

- Creating a network of complete streets that provide perceptibly safe and comfortable trips have the biggest impact on reducing VMT for this overall strategy.
- A comprehensive strategy involving not only infrastructure, but programming, education and other policies will significantly increase bicycling and walking (Handy, et al. 2010).
- Land use strategies, such as locating high-use destinations and essential services within 20 minutes of biking or walking as well as increasing the number of people living and working in such an area will also impact the success of this strategy.
- As communities become more diverse, there is a need to ensure that active transportation investments are relevant to multiple demographics. Individualized marketing campaigns and public education and outreach can help ensure relevancy and sensitivity to diverse community perspectives.

The following key elements of complete streets provide potential ways to focus investments:

- Identify and close key gaps in multi-use paths and trails, bridge crossings, pedestrian crossings of busy roadways and gaps in bike lanes.
- Improve pedestrian and rider safety with crossing treatments such as signals, street and intersection treatments, and medians. Un-safe crossings have been identified as a major barrier to biking and walking (Willamette Pedestrian Coalition, 2010).

- Focus on the routes that connect to jobs, essential services, schools, and public transportation.
- Focus on routes that serve the most people and jobs (Cambridge Systematics 2011).
- Focus on providing facilities that create more attractive and perceptibly safe trips. A Portland State University bike study found trails to be the most attractive, followed by bike boulevards and bike lanes, respectively.
- Focus on providing elements that support biking and walking, including street designs, street lighting, signage/wayfinding and end-of-trip facilities (e.g., bike parking, showers and storage).
- Utilize intelligent transportation systems solutions that can support and encourage active transportation with High-intensity Activated crossWalk (HAWK) signals and signal timing for bicycle trips.
- Ensure that all areas follow a policy that takes into account all users of streets and has the goal of completing the streets with adequate facilities for all users (Cambridge Systematics 2011).
- Create non-motorized zones in urban areas (Cambridge Systematics 2011).

Where to apply and scale of application

Connectivity of the network is the key to its success, so comprehensive application is necessary. However, certain areas can be targeted to maximize the most benefits as soon as possible. For example:

- Focus investments in the network in the Portland Central City, regional and town centers, corridors, main streets and station areas.
- Give priority to areas with higher levels of population, jobs and mixed-use development.
- Provide for longer distance non-motorized trips on active transportation corridors.
- Invest in denser areas to yield the greatest number of new users (Cambridge Systematics 2011).
- Focus on access to schools to expand travel options for youth.
- Connect to high-use destinations to increase non-motorized trips.

Potential timing and phasing of implementation

The timing and phasing for implementation depends upon factors such as funding levels, topography, acquisition of right-of-way for off-street facilities, and political appetite to fund facilities such as buffered bike lanes. An increase of five percent in funding for bicycle and pedestrian facilities would mean that a regional system could be completed in 50 years instead of 150 years under business-as-usual funding.

Case Study: The Effects of Bicycle Investments in Amsterdam, Netherlands

The City of Amsterdam, Netherlands, provides an international example of a city that has achieved a bicycling mode split of over 37 percent. Like many cities after WWII, Amsterdam saw a dramatic decrease in the number of people bicycling as auto ownership grew and suburbanization increased. In 1955, 75 percent of the population traveled by bike, but by 1970 that number had dropped to 25 percent.

To counter the decline of bicycle use, the Amsterdam City Council increased funding for constructing facilities, especially separated bike paths, and changed policies to encourage more bicycling; the city has 249 miles of separated bike paths and lanes completed. By 2005, the number of cyclists had increased to 37 percent. Amsterdam's bicycling and pedestrian network is well connected to public transportation (Fietsberaad 2010).

Active transportation and complete streets solutions are relatively inexpensive to implement, but can require prioritization for completion. Despite this, bicycle and pedestrian facilities and rights-of-way should be required as part of development.

To speed implementation, pedestrian and cycling projects should be un-bundled from larger road projects that may not be realized for many years. The *Moving Cooler* Report identified a long-term time frame: "investments in transportation options… are realized in the outer decades" (e.g. 2030 and beyond) (Cambridge Systematics 2009). This may be because transportation options were bundled with land use changes in that analysis.

Some case studies indicate that with policies dedicated specifically to completing active transportation systems and focused funding, cities can build the infrastructure necessary to see a dramatic shift in mode share in a relatively short period of time. For example, in roughly six years, Seville, Spain was able to implement a rapid build-out of bicycle infrastructure and increased its bicycle mode share from 0.2 to 6.6 percent (Cruz 2011).

Who implements

Local and state governments typically construct biking and walking facilities. Funding for implementation comes from a variety of sources and implementing agencies that must often piece together funding to complete one project. Regional agencies provide coordination and planning for routes that cross multiple jurisdictions. Advocacy groups for bicycling, walking, trail construction and access to transit play a role in determining which projects are built.

In some cases, private companies will build or sponsor routes. For example, London's cycle highways are sponsored by Barclay's Bank through an exclusive advertising contract that has provided millions of dollars to construct the 25-mile plus routes. The Indianapolis Cultural Trail, Philadelphia's Schuylkill River Trail, and the East Coast Greenway leveraged considerable support from private foundations to secure federal Transportation Investment Generating Economic Recovery (TIGER) grants.

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A COMMUNITY DESIGN STRATEGY

A major component of a balanced, regional multi-modal transportation system is transit. Transit efficiently links other travel options in the region, including bicycling and walking. Additionally, park-and-ride lots offer drivers a transit connection and an alternative to driving alone to work or other destinations. TriMet bus and MAX light rail operations as well as other emerging transit service providers give individuals transportation options and will play an important role in shaping the future growth of the Portland metropolitan region in addressing climate change.

The effectiveness of transit service as a GHG reduction strategy is the focus of this section. High quality transit service is not just a single strategy to be considered in isolation, but rather should be viewed in conjunction with compact mixed-use development, higher residential and employment densities, a mix of land uses, regional growth management (e.g. urban growth boundary), and pedestrian and bicycle friendly design. Increasing the reliability, coverage and frequency of transit aims to support mixed-use development strategies and reduce the amount or distance people need to drive, decreasing VMT, and thereby reduce related GHG emissions. This strategy will focus on transit performance and the effectiveness of transit service as a GHG reduction strategy.

Existing research findings

Four of the five P's of mixed-use development--People, Places, Physical form, and Pedestrian and bicycle connectivity--are related to the previous two strategies. Research for public transit service strategies focuses on the "Performance" component of the five P's.

The Five P's of mixed-use development

As part of its strategic planning process, Metro's Transit Oriented Development Program explains the relationship of development patterns to travel behavior by analyzing the Five P's of transit oriented development.

People: Intensity of development and/or population in an area

Places: Mix of uses, especially neighborhood serving goods and services

Physical Form: The built environment as experienced and navigated by the pedestrian

Pedestrian/Bicycle Connectivity: Access to sidewalks and bikeways

Performance: High quality, frequent bus and rail service

Performance is addressed in this strategy section.

The research centers on the effects of transit service on total ridership and per capita ridership rather than the effects on VMT. Few studies were identified that directly test the effect of transit service strategies on VMT or GHG emissions reduction. Instead, there is a catalog of numerous transit related strategies that have been shown to increase transit ridership to varying degrees. Inferences can be made, then, about the effectiveness of transit service strategies on reducing VMT and GHG emissions.

Transit strategies generally fall into four categories: frequency, system expansion, fares and transit access improvements. An extensive list and summary of studies documenting the effects of transit service strategies on ridership is provided in Transportation Cooperative Research Program Report Number 95 (Evans 2004).

Frequency

Providing high quality, frequent transit service is one of the most effective ways to increase ridership. Upgrades such as more frequent off-peak service can attract more riders, including those who might have otherwise driven private automobiles. Frequency is especially important for attracting riders who take short, local trips, because the time spent waiting for transit to take a short trip is a proportionately larger component of the total travel time than for a longer trip. A ten-minute wait for a five-minute ride is less attractive than a ten-minute wait for a forty-minute ride.

The effectiveness of frequency improvements will vary widely depending on the type and location. Improvements in more dense urban areas with greater transit infrastructure may offer greater opportunities for GHG emissions than more suburban auto-oriented locations.

Frequency strategies include:

- Increases in frequency and number of scheduled vehicle trips
- Increases in service hours by adding and lengthening service days
- Express service routes
- Regular schedules with easy to remember departure times and improved coordination at transfers
- Service reliability changes through predictable arrival times

A Bus Rapid Transit system, where bus-only lanes allow for frequent, high capacity service, can reduce GHG emissions from 0.02 to 3 percent. Increasing the service frequency can result in a 0.02 to 2.5 percent emissions reduction (CAPCOA 2010).

System Expansion

Expansions in the transit system can help a region concentrate development and growth in centers and corridors. Extending the system both through HCT expansion and bus service expansion to new areas can increase the number of passengers that the transit system carries and potentially shift more riders from private automobile.

System expansion strategies include:

- New transit systems through implementing new bus or rail service that does not currently exist
- Comprehensive service expansion of existing system
- Restructuring service of existing system
- Changed urban and suburban coverage by extending, adding, or modifying transit service for new developments
- Routes connecting disadvantaged neighborhoods to job locations
- Expanding the transit network, which can result in reducing GHG emissions by 0.1 to 8.2 percent (CAPCOA 2010).

Case Study: Better Connections and Service Changes in East Multnomah County Increase Ridership

In 2009, TriMet needed to implement an 18-month reroute on Line 12-Barbur/Sandy Blvd due to construction in Fairview, Oregon. This segment of the line serves a large percentage of Spanish-speaking riders who have limited English proficiency. TriMet developed a survey tool in Spanish and interviewed riders about their daily trips on the bus to see how the route would affect them. A new route was implemented and weekly ridership in the area grew by 69 percent. Riders and staff from El Programa Hispano, a social service agency that serves low-income Latinos in Portland, requested that the new route be made permanent to provide better access to local employers. TriMet agreed and the route change is permanent.

Fares

Cost of travel is one of the key factors in a traveler's decision-making process. Lowering transit service costs by reducing or modifying fares will increase transit ridership and potentially reduce VMT. However, the effectiveness depends on the design of the fare system and the cost.

Fare strategies include:

- Reducing or not charging for general fares
- Changing pricing relationships, e.g. discount for multiple-ride tickets
- Changing fare categories by modifying fares for multiple-ride tickets, unlimited passes, school fares, or express bus fares
- Changing the basis on which fares are calculated, e.g. flat fare for entire system or distance-based fare
- Extending transfer times for transit riders

Transit access

All transit trips begin and end with different modes of access even if stations are mere steps from origins and destinations. Transit riders access transit via walking, bicycling, bus, rail, carpools and private automobiles.

At some point in their trip, all transit riders are pedestrians. The environment where people walk to and from transit facilities is a significant part of the overall transit experience. An unattractive or unsafe walking environment discourages people from using transit, while a safer and more appealing pedestrian environment may increase ridership. Likewise, high quality local and regional bicycle infrastructure extends the reach of the transit system.

Transit access strategies include:

- Increasing the number of park-and-ride facilities
- Increasing development near high frequency transit
- Increasing pedestrian and bicycle access to transit

Caveats on research

Few of the research studies identified controlled for other factors that may also influence transit ridership, such as the other four P's of mixed-use development. Compact land-use development contributes strongly to reducing VMT by generating more walking and biking trips and shorter auto trips.

Increases in transit ridership have not been demonstrated to translate directly into reduced VMT and GHG emissions when considered independently of land use. Research suggests, however, that public transportation availability has a secondary effect on VMT, with a magnitude of 1.9 beyond the primary effect of reducing private vehicle trips with public transit trips. This significant secondary effect, generated through more efficient land use patterns, suggests that public transit is helping to bring about such land use patterns (ICF International 2008).

Additionally, there is significant variability in the estimated effects of various transit service strategies, depending on the characteristics of individual transit systems. As well, the length of time for the full effect of a strategy to be realized should also be taken into consideration. Finally, the research suggests that multiple transit service strategies have synergy, with a greater overall effect compared to the sum of individual strategies.

Case Study: Bay Area Transit Actions Reduce Greenhouse Gas Emissions

Frequency
In January 2008, the Bay Area Rapid Transit (BART) District in San Francisco implemented headway improvements in the off-peak evenings and weekends, reducing wait times from 20 to 15 minutes. This increase was estimated to attract an additional 700 riders, decreasing VMT by 3.3 million per year, and eliminating 1,000 metric tons of CO_2 emission. The additional cost of operations is about $2 million per year, costing $2,000 per metric ton of CO_2 reduced (Nelson\Nygaard 2008).

System expansion
The BART District commissioned a study to examine the planned extension of the heavy-rail transit A-line to Warm Springs. Analysis showed that the Warm Springs Extension would produce a 73 million miles reduction in annual VMT by 2025. This is a reduction of approximately 27,000 metric tons of annual GHG emissions. The estimated capital cost of the project is around $750 million. The cost per ton eliminated was estimated to be around $2,000 per ton of CO2, not including the emissions from construction.

Fares
The 2008 BART District report examined the cost effectiveness and GHG emissions of various transit service strategies. BART District's most effective fare programs are those that focus on adding off-peak and reverse commute travel. This takes advantage of excess capacity, but retains higher fares for peak-hour commuters. One specific BART District program targeted off-peak weekend family travel, allowing children accompanied by a paying adult to ride free on Saturdays during the summer. The ridership increases were used to calculate potential GHG emission reductions, resulting in approximately 1,500 metric tons CO_2 from 15,000 additional adult trips.

Transit access
The lack of a last mile connection to high capacity transit service is often a barrier. Often people cannot get from stations to employment or retail centers in a convenient and direct manner, opting to drive instead. The 2008 BART District study looked at feeder service as a strategy for bridging this last mile gap. A BART operated shuttle service was estimated to eliminate eight million VMT and a reduction of 1,800 metric tons of CO_2 per year. However, the expense of the shuttle service operations varies greatly and makes it difficult to estimate the general cost-effectiveness.

Co-benefits and synergy with other strategies

Co-benefits

Beyond reducing VMT and GHG emissions, transit service strategies have the potential to provide other important co-benefits to a community, including:

Public health and safety benefits:

- Increased physical activity from walking and biking, leading to reduced risk of obesity, diabetes, heart disease and premature death
- Enhanced public safety; reduced risk of traffic injuries and fatalities
- Improved air quality and fewer air toxics emissions, leading to reduced risk of asthma, lung disease and premature death

Environmental benefits:

- Lower levels of pollution
- Less energy used

Economic benefits:

- Job opportunities with greater investment in public transit
- Increased property values and leveraged private investment, increasing local tax revenues
- Increased access to jobs, goods and services
- Reduced fuel consumption; reduced dependence on foreign oil
- Consumer savings in transportation
- Increased cost effectiveness of transit through improved ridership

Synergies with other strategies

Synergy exists when a combination of two or more strategies enhances the potential GHG emissions reduction from an individual strategy. Public transit service is synergistic with several other strategies including:

- Mixed-use development in centers and transit corridors
- Active transportation and complete streets
- Parking pricing
- Tolls, fees, and insurance
- Employer-based commuter programs
- Traffic management
- Fleet mix and turnover

Considerations moving forward

In isolation, transit service strategies can be estimated to have varying, small impacts on VMT and GHG emissions. However, the research does suggest that the presence of transit may have a more important secondary effect when combined with other strategies.

Compact mixed-use development strategies have been estimated to reduce GHG emissions by up to 25 percent when implemented in combination with other strategies aimed at increasing walking, biking and use of transit. In addition, parking management strategies have a strong relationship to shifting trips to transit. As the secondary effects of transit service strategies have been shown to have a multiplier effect when combined with other strategies, they should be considered in conjunction with other efforts.

Implementation of this strategy must also incorporate transit equity and environmental justice considerations in decisions about:

- transit service to low-income neighborhoods and communities of color, students and non-English speaking populations; and
- placement of bus stops and shelters and allocation of new low-floor buses
- neighborhood impacts like air quality, traffic and noise
- potential displacements of businesses and residences
- neighborhood access to bus stops and light rail station areas

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Pricing Strategies

Parking Pricing, Tolls, Fees and Insurance

Pricing strategies charge users directly for using transportation facilities. Research shows parking pricing, congestion pricing, cordon pricing, mileage-based fees, and pay-as-you-drive-insurance can be used to reduce GHG emissions. The research also suggests that these strategies are more successful when implemented in combination with community design and other management strategies. The potential reductions highlighted below are not additive and vary depending on the combination of strategies implemented.

PARKING PRICING

Parking fees: workplace parking fees, long-term or short-term fees in mixed-use areas and residential parking permits

Limiting parking supply to meet demand: establishing maximum parking requirements or creating a shared parking provision

Up to 20 percent

Reduction in commute trips, depending on the daily rate charged for workplace parking

5 to 12 percent

Potential VMT reduction when parking supply is limited to meet demand

TOLLS AND FEES

Cordon pricing: A vehicle is charged a toll when passing through a cordon around a congested area, such as a central city

Congestion pricing: Charging tolls that vary depending on roadway congestion to help manage traffic flow

Mileage fee: A fee is collected according to the number of miles that a vehicle is driven

20 percent

Reduction in CO_2 since cordon pricing was implemented in London

20 percent

Reduction in GHG emissions by 2050 if congestion pricing alone was implemented

1 to 5 percent

Reduction in GHG emissions by 2050 if a mileage fee alone was implemented

INSURANCE

Pay-as-you-drive insurance (PAYD): A PAYD insurance premium is based on annual miles driven per vehicle; the crash risk increases the more the vehicle is driven

1 to 3 percent

Reduction in GHG emissions by 2050 if pay-as-you-drive insurance alone was implemented

CO-BENEFITS

Public health and safety benefits

- Reduced number of uninsured motorists
- Improved air quality and fewer air toxics emissions, leading to reduced risk of asthma, lung disease and premature death

Environmental benefits

- Lower levels of pollution

Economic benefits

- More available land for development or preservation
- New revenues
- Reduced fuel consumption; reduced reliance on foreign oil
- Consumer savings in transportation

SYNERGY WITH OTHER STRATEGIES

- Mixed-use development in centers and corridors
- Active transportation and complete streets
- Public transit service
- Public education and marketing
- Employer-based commuter programs
- Traffic management

IMPLEMENTATION

Pricing strategies have been shown to achieve reductions in GHG emissions and to provide other benefits to communities, including congestion relief. They prompt reductions in the number of miles driven and can spur improvements in fuel economy and the purchase of fuel-efficient vehicles.

Research shows the greatest potential for reducing GHG emissions exists in PAYD insurance, mileage fees and parking pricing. PAYD insurance and a mileage fee could be implemented at the state level. Parking management and pricing strategies are traditionally implemented at the community level in commercial districts, downtowns, and main streets.

Public acceptance, communications, evaluation of benefits and costs (including equity and fairness) and use of revenues generated pose specific issues and challenges to be addressed. As pricing strategies are considered, it is important to evaluate their effect on other parts of the region's transportation system and equity to ensure any unintended consequences are identified and addressed.

Over the last decade, communities across the United States have become more aware of the impact of parking on congestion, mode share, air quality, compact development, and the pedestrian environment. Historically, the problem of parking has been viewed as an issue of too little supply, but recently, this view has shifted to recognizing the poor management of the existing parking supply.

Parking is a crucial link between land use and transportation because parking facilities affect the design and form of commercial and residential development. Parking influences travel mode choices, directly affecting the form of urban infrastructure, as well as the amount of GHG emissions generated.

Parking pricing policies can influence GHG emissions by facilitating or discouraging certain types of travel during different times of the day. Pricing strategies can be grouped into three categories (California ARB 2010):

- Long-term and short-term parking fee differentials
- On-street fees and residential parking permits
- Workplace parking pricing (see Employer-Based Commuter Programs section)

Existing research findings

A literature review did not yield specific studies that directly quantified the impact of all three categories of pricing. Instead, a number of studies were found to examine the effects of parking pricing policies on parking demand. Parking pricing is usually included in a bundle of components of travel demand management tools. Studies that examined impacts on VMT mostly dealt with the impacts of eliminating a work place parking subsidy at specific sites.

Some research found parking pricing can have significant transportation impacts. Even modest parking fees can affect vehicle travel behavior and vehicle emissions. The price elasticity of vehicle travel with respect to parking price ranges from –0.1 to –0.3 (a 10 percent increase in parking charges reduces vehicle trips by 1-3 percent), depending on demographic, geographic, travel choice and trip characteristics (Vaca and Kuzmyak, 2005). Pricing that applies to commuter parking tends to be particularly effective at reducing peak-period travel.

A Washington State Department of Transportation study used detailed data on various urban form factors to assess their impacts on vehicle travel and carbon emissions (Frank, et al. 2011) . The analysis indicates that parking pricing can have significant impacts on vehicle travel and emissions. Increasing parking fees from approximately $0.28 to $1.19 per hour reduced VMT 11.5 percent and vehicle emissions 9.9 percent.

Shifting from free to cost-recovery parking (prices that reflect the full cost of providing parking facilities) typically reduces automobile commuting by 10-30 percent, particularly if implemented with improved transit and other complementary demand management strategies (Comsis Corp., 1993; Hess, 2001). However, pricing parking in just one area may simply shift vehicle trips to other locations with little reduction in overall vehicle travel (Hensher and King, 2001). About 35 percent of drive-alone commuters would likely switch modes in response to $20 per month parking fees, even if offset by a worksite transportation voucher (Kuppam, Pendyala and Gollakoti, 1998).

One study indicates that a $1.37 to $2.73 increase in parking fees reduces auto commuting 12-39 percent, and if matched with transit and rideshare subsidies, reduces total auto trips by 19-31 percent (ICF International 1997). A survey of automobile commuters found that nearly 35 percent would consider shifting to another mode if they were required to pay for parking, with fees of $1-3 per day in suburban locations and $3-8 per day in urban locations (Kuppam, Pendyala and Gollakoti, 1998). Table 3 shows the typical reduction in automobile commute trips that can result from parking pricing for different types of land uses.

Table 3. Percent Vehicle Trips Reduced by Daily Parking Fees

Worksite Setting	$1	$2	$3	$4
Low density suburb	7%	15%	25%	36%
Activity center	12%	25%	37%	47%
Regional CBD/Corridor	18%	32%	43%	50%

From Comsis Corporation, 1993. Fees in 1993 U.S. dollars. Percentages have been rounded.

The *Moving Cooler* report (Cambridge Systematics 2009) found that charging $100 to $200 annually for residential area parking permits would yield a 0.09 to 0.36 percent reduction in VMT. Research on the modeling of on-street public parking pricing has yielded a 2.8 to 5.5 percent reduction in VMT. Limiting the parking supply, by establishing maximum parking requirements or creating a shared parking provision, is even more effective and can reduce VMT by 5 to 12.5 percent. Other research compared multiple parking pricing studies, including European cities, and found a median VMT reduction of two percent (Dueker et al. 1998).

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Caveats on research

Specific evidence showing the direct impact of parking pricing on VMT and GHG emissions is limited and most evidence was obtained from studies almost fifteen years old. Additionally, parking pricing is often implemented and evaluated in conjunction with other travel demand management strategies. Special attention needs to be given to places where transit or bicycle and pedestrian infrastructure is lacking or where ample parking alternatives exist, which may lead to lower results than the research indicates. More current and tailored research (e.g., specific to communities in the Portland region) is needed to build understanding of the fiscal and community implications of this strategy.

Co-benefits and synergy with other strategies

Co-benefits

Beyond reducing GHG emissions, the parking pricing strategy has the potential to provide other important benefits to a community.

Public health and safety benefits:

- Improved air quality and fewer air toxics emissions, leading to reduced risk of asthma, lung disease and premature death

Environmental benefits:

- Lower levels of pollution

Economic benefits

- More available land for development or protection
- New revenues
- Reduced fuel consumption; less dependence on foreign oil
- Increased cost effectiveness of transit through improved ridership

Synergies with other strategies

Synergy exists when a combination of two or more strategies enhances the potential GHG emissions reduction from an individual strategy. Parking pricing is synergistic with several other strategies including:

- Mixed-use development in centers and corridors
- Active transportation and complete streets
- Public transit service
- Employer-based commuter programs
- Traffic management

Considerations moving forward

Parking pricing is an important strategy in shifting trips to transit and supporting compact mixed-use development. Parking pricing works best when used in a complementary fashion with other strategies because of its potential to further reduce GHG emissions.

Parking pricing is usually implemented by local governments or developers and businesses that own and manage parking facilities. Implementation may require support and coordination among local governments, business associations, individual businesses, neighborhood associations and individual residents.

More research is needed to substantiate a direct link between parking pricing strategies and GHG emissions reductions to build understanding of this strategy. In isolation, parking pricing can be estimated to have varying impacts on VMT and GHG emissions. Research suggests that the presence of multiple pricing strategies, including cordon pricing, congestion pricing, mileage fees, and pay-as-you-drive insurance, may result in a larger GHG emissions reduction than implementation of individual strategies.

Charging drivers based on the amount, location, and/or timing of automobile travel is a pricing strategy. By charging drivers a price that is closer to the marginal cost of driving, changes in travel behavior can be induced, resulting in a reduction of GHG emissions. The intent of pricing is to provide a financial incentive for drivers to reduce both drive-alone and total number of trips, as well as induce travel during less congested times of day. Research has documented GHG emissions reductions from these types of strategies.

Cordon Pricing

Cordon pricing requires users to pay a toll to enter or drive within a congested area such as a central city or other major activity center during times of heavy traffic. This pricing strategy is best suited for heavily congested urban centers with a limited number of access points.

Congestion Pricing

Congestion pricing is an overarching term used to describe measures that reduce congestion by charging drivers tolls that vary by time of day or the amount of traffic on a roadway. This can be accomplished either through an independent electronic system using roadside readers, as a rate adjustment to an electronically-collected mileage fee, or a combination of the two, for time-of-day travel in specific geographic areas where congestion prevails. Tolling congested facilities with fees that are adjusted dynamically based on prevailing traffic conditions can help achieve a desired level of service. This strategy is best suited for implementation on regional transportation facilities.

Mileage Fee

The mileage fee, also known as a road use fee, vehicle miles traveled (VMT) fee or per-mile charge, is collected according to the number of miles a vehicle is driven on the road system. A mileage fee requires a periodic odometer reading either manually or electronically. Realistic possibilities for electronic collection are limited to centralized collection and fuel pump collection. Centralized collection involves transferring data to a center that sends periodic billings to the motorist. Fuel pump collection involves transferring data while at the gas pump with payment as part of the fuel purchase.

A mileage fee has the potential to be a significant source of revenue. While some insurance providers offer discounts to lower-mileage drivers, drivers still pay a fixed rate each year, which means they do not have an opportunity to save for every mile not driven. This type of fee can provide additional benefits to the region or state, by distributing the cost of travel more equitably among users – e.g., the less an individual drives, the less they pay. In addition, a mileage fee can be set to vary by the characteristics of the vehicle driven, such as a slightly higher per-mile fee for driving a less fuel-efficient vehicle. A mileage fee has the greatest impact when implemented on large scales, in particular at the state level.

Pay-as-you-drive insurance (PAYD)

This pricing strategy converts a portion of liability and collision insurance from dollars-per-year to cents-per-mile (or cents-per-minute/hour if advanced tracking technology is utilized) to charge insurance premiums based on the total amount of miles driven per vehicle on an annual basis and other important rating factors, such as the driver's safety record. If a vehicle is driven more, the crash risk consequently increases. PAYD insurance charges policyholders according to their crash risk. Because the cost of PAYD insurance varies with the number of miles driven and other rating factors, there is an incentive for a motorist to drive less to save money. It has been estimated that a PAYD insurance rate of four to 6 cents per mile could reduce the VMT from light vehicles by 3.8 percent.

PAYD insurance premiums benefit everyone involved: the insurance company through improved accuracy and reduced claims costs, the driver through a controllable variable rate, and the environment by reducing VMT (Hagerbaumer 2011). Under PAYD insurance, the expected reduction in claims for crashes is 1.34 times the reduction in mileage because of fewer multicar collisions (Cambridge Systematics 2009a). PAYD insurance is best implemented by private companies with encouragement from the state, with the possibility of assistance from the federal government.

Existing Research Findings

All of the pricing strategies noted above have been shown to reduce total vehicle trips and/or VMT, both of which are directly linked to reduced GHG emissions from light vehicles. The extent to which GHG emissions are reduced depends in large part on the extent to which each individual strategy is deployed.

Cordon Pricing

Research studies have shown that, depending on the level of deployment, cordon pricing, on its own, can potentially achieve GHG reductions of approximately 0.1 percent by 2050 (Cambridge Systematics 2009b). Pilot projects in Stockholm and London have experienced significantly greater GHG emissions reductions – up to 20 percent.

Case Study: Cordon Pricing Pilots in Stockholm and London

The city of Stockholm, Sweden implemented a pilot cordon pricing program in January of 2006 and within six months exhaust emissions dropped by 14 percent and vehicle trips decreased by 22 percent.

Cordon pricing in central London (implemented in 2003) has reduced congestion levels by 30 percent and the amount of traffic entering the priced zone by 18 percent. The decreases in congestion equate to an estimated 20 percent reduction in CO_2 emissions from road traffic in central London.

Congestion Pricing

Research on congestion pricing yields mixed results:

- The *Moving Cooler* study estimated that congestion pricing could achieve GHG reductions of 0.8 to 1.8 percent by 2050, depending on the scale of deployment (Cambridge Systematics 2009b).
- Two ODOT studies indicate the need for further research. In the Portland region a study looked at variable tolls on Cornelius Pass Road and results showed an expected increase in VMT and emissions due to out of direction travel caused by diversion to other routes to avoid the toll (ODOT 2010).
- The Road User Fee Task Force, commissioned by Oregon Governor Kitzhaber, found that congestion pricing could be supported by a mileage fee as well as collection of local revenues and other "zone-oriented" features. The combination pricing strategy tested in the pilot program resulted in a 22 percent reduction in driving during peak periods (ODOT 2007).

Mileage fee

Recent studies have estimated that a mileage fee could achieve GHG reductions of 0.4 to 5 percent by 2050 (Cambridge Systematics 2009b). Another report estimated that a five-cent per mile fee could reduce transportation-related GHG emissions by three percent or more within five to ten years (U.S. DOT 2010). The Road User Fee Task Force, commissioned in 2001, considers the mileage fee to be the principal general revenue source for a new system to ultimately replace the gas tax for transportation funding. Of the 299 motorists participating in the ODOT mileage fee study, 91 percent said they would agree to continue paying the fee in lieu of the gas tax if the law were statewide (ODOT 2007).

Case Study: Oregon Mileage Fee Concept Pilot Program

Oregon's version of a per-mile charge—the Oregon Mileage Fee Concept—was the basis for a recently completed pilot program. A 2007 ODOT pilot study equipped 285 volunteer vehicles with on-board devices to test a potential VMT tax and peak period pricing system in Oregon. Program participants were found to reduce their total VMT by 12 percent under a VMT fee (ODOT, 2007). When a charge of ten cents per mile was implemented in a congestion zone, participants reduced their total VMT by 22 percent (Cambridge Systematics 2009a).

Pay-as-you-drive insurance

The *Moving Cooler* study estimated that PAYD insurance could achieve GHG reductions of 1.2 to 3.3 percent by 2050 (Cambridge Systematics 2009b). A study in Massachusetts found that switching all Massachusetts drivers to PAYD could reduce fuel consumption by 12.5 percent and VMT by three to 14 percent (Ferreira & Minikel 2010). Another study found that if all fixed costs of car insurance were converted to PAYD insurance, the result would be an estimated eight percent reduction in annual VMT (Cambridge Systematics 2009a).

Case Study: PAYD Insurance in King County, Washington

King County, Washington engaged insurance companies and launched a pilot PAYD insurance partnership with Unigard Insurance, with support from the Federal Value Pricing Pilot Program. The Mileage Based Auto Insurance Project has 5,000 participants from across the state over the course of five years, with pilot completion in 2012. This project may prove to be a useful example of a metropolitan-scale public-private PAYD insurance partnership.

For the King County, Washington case study, see the FHWA project website for posted results, expected sometime in 2012: http://ops.fhwa.dot.gov/tolling_pricing/value_pricing/projects/not_involving_tolls/autousecostsvariable/wa_payd_seattle.htm

Caveats on research

Mileage fee

At this time, it is unclear which institutional framework (national, multi-state, state, or regional) is appropriate for implementing a mileage fee. Different agencies and institutions may need to provide oversight depending on the shape the system takes. In addition, privacy advocates are concerned about the onboard monitors required to implement the strategy. Alternatively, other advocacy groups may be concerned that replacing the gas tax would eliminate the incentive to purchase more fuel-efficient vehicles (Council of State Governments 2010). As noted in the research, though, a mileage fee can be set to vary by the characteristics of the vehicle driven, such as a slightly higher per-mile fee for driving a less fuel-efficient vehicle.

Pay-as-you-drive insurance

As PAYD insurance becomes available to more households, the potential savings may afford some households to increase their ownership of vehicles, especially if the annual VMT per car is low. This could potentially add additional vehicle traffic and offset some of the expected GHG emissions reduction (Litman 2011a).

Co-benefits and synergy with other strategies

Co-benefits

Beyond reducing GHG emissions, the tolls, fees and PAYD insurance have the potential to provide other important benefits to a community:

Public health and safety benefits:

- Enhanced public safety
- Improved air quality and fewer air toxics emissions, leading to reduced risk of asthma, lung disease and premature death

Environmental benefits:

- Lower levels of pollution

Economic benefits:

- New revenues

- Increased cost effectiveness of transit investments through improved ridership

Synergies with other strategies

Synergy exists when a combination of two or more strategies enhances the potential GHG emissions reduction from an individual strategy. Tolls, fees and PAYD insurance are synergistic with several other strategies including:

- Public transit service
- Public education and marketing
- Employer-based commuter programs
- Traffic management

Considerations moving forward

Pricing approaches, including various forms of road pricing, parking pricing and mileage-based user fees offer potential GHG reductions and other benefits to communities, including congestion relief. Public acceptance, communications, evaluation of benefits and costs (including equity and fairness) and use of revenues generated pose specific issues and challenges to be addressed.

The fairness of a given type of pricing mechanism depends on how it is structured, what transportation choices are provided to users and which aspects of equity are most relevant and important to consider. It will be important to more fully understand the potential issues, impacts and tradeoffs between benefits and costs of different pricing strategies. As pricing strategies are considered, it is important to evaluate their effect on other parts of the region's transportation system and equity to ensure any unintended consequences are identified and addressed.

Research shows the greatest potential for reducing GHG emissions exists in a mileage fee and PAYD insurance. Since implementation of these strategies is not necessarily well-suited for the regional level, a mileage fee could be deployed at the regional or state level, and PAYD insurance is best deployed at the state level by the private sector with public partnership.

In 2003, Oregon passed House Bill 2043, which offers a tax credit to insurers who offer PAYD insurance. The tax credit was extended in 2009 under HB 2001. The legislation provides a tax credit of $100 per eligible vehicle under a policy that is at least 70 percent mile- or time-based.[4] Although no insurance company to date has qualified for the tax credit, the Oregon Environmental Council believes it has attracted insurance companies to pilot new policies in Oregon that offer steeper discounts for less driving (Hagerbaumer 2011).

Other potential strategies for implementation at a regional level are cordon pricing and a system of variable congestion pricing on freeways and major arterials, although public acceptance of these strategies is limited.

[4] See details of the tax credit under the Oregon Revised Statutes 317.22: http://www.leg.state.or.us/ors/317.html

Marketing and Incentives Strategies

Education, Marketing, and Commuter Programs

Education and marketing programs are effective strategies to reduce GHG emissions; they are less costly to implement than building new infrastructure, and are widely supported by the public. The research also suggests that these strategies are more successful when implemented in combination with community design and pricing strategies. These strategies include teaching the public to drive and maintain vehicles to operate more efficiently and building awareness of travel choices; they can be tailored to a diverse range of perspectives and needs. The potential reductions highlighted below are not additive and vary depending on the combination of strategies implemented.

PUBLIC EDUCATION

Eco-driving: a combination of driving behaviors and techniques that result in more efficient vehicle operation, reduced fuel consumption and reduced emissions

Travel options education: public programs that raise awareness of smart trip choices including carpooling, vanpooling, ridesharing, telecommuting, biking, walking and riding transit

5 to 33 percent

Improvement in fuel economy when using gentle acceleration and braking while driving

7 to 23 percent

Improvement in fuel economy when observing speed limit and not exceeding 60 mph (where legally allowed)

INDIVIDUALIZED MARKETING

Individualized marketing: an outreach method where individuals interested in making changes to their travel behavior participate in a program that is tailored to their specific needs

4 to 19 percent

Reduction in GHG emissions from trip-related emissions in a range of individualized marketing programs

EMPLOYER-BASED COMMUTER PROGRAMS

Financial incentives: transit pass programs, offering cash instead of parking (parking cash-outs), parking pricing, and tax incentives (both business and individual)

Facilities and services: include ride-matching and carpooling programs, end-of-trip facilities (i.e. showers, bike parking), guaranteed ride home, and events and competitions

Flexible scheduling: telecommuting and compressed or flexible workweeks

Up to 20 percent

Reduction in commute trips, depending on the daily rate charged for workplace parking

Up to 13 percent

Reduction in commute trips when employers provide vanpools or shuttles to transit stations or commercial centers

Up to 6 percent

Reduction in commute trips when flexible scheduling is encouraged

CO-BENEFITS

Public health and safety benefits

- Increased physical activity from walking and biking, leading to reduced risk of obesity, diabetes, heart disease and premature death
- Enhanced public safety; reduced risk of traffic injuries and fatalities
- Improved air quality and fewer air toxics emissions, leading to reduced risk of asthma, lung disease and premature death

Environmental benefits

- Lower levels of pollution
- Less energy use

Economic benefits

- Job opportunities
- Increased access to jobs, goods and services
- Consumer savings
- Reduced fuel consumption; reduced reliance on foreign oil
- Increased cost effectiveness of transit investments through improved ridership

SYNERGY WITH OTHER STRATEGIES

- Mixed-use development in centers and corridors
- Active transportation and complete streets
- Public transit service
- Tolls, fees and insurance
- Individualized marking
- Traffic management
- Vehicle technology and fuels

IMPLEMENTATION

Education and marketing programs are effectively implemented at local, regional and state levels by a variety of public, private and non-profit partners. Employer-based commuter programs like Oregon's Employee Commute Options (ECO) Program or *Drive Less Save More* campaign are managed and coordinated by state, regional and local governments, while businesses are responsible for implementation. Education and marketing programs are often successful when targeting neighborhoods with existing access to transportation options or planned transportation improvements.

A MARKETING AND INCENTIVES STRATEGY

Public education and marketing are effective strategies in reducing GHG emissions. Moreover, they are less costly than building new infrastructure, and are widely supported by the public. These strategies provide the necessary platform from which to encourage eco-driving among the general public as well as through other programs such as the *Drive Less Save More* campaign, which is implemented by state, regional and local public and private partners.

Eco-driving involves educating motorists on how to drive in order to reduce fuel consumption and emissions. This combination of behaviors and techniques results in more efficient vehicle operation, reduced fuel consumption, and reduced emissions:

- Driving at lower speeds
- Changing gears properly
- Avoiding rapid acceleration and braking
- Planning trips in advance
- Maintaining proper vehicle tire pressure
- Removing unnecessary weight from the vehicle

The actions under the eco-driving moniker have broad potential to reach the nation's entire fleet of 240 million passenger vehicles. This strategy offers easily implemented ways to save money and reduce the region's GHG emissions. In addition to encouraging eco-driving, public education and marketing can raise public awareness about the benefits of driving less and riding transit, carpooling, ridesharing, telecommuting, biking, and walking.

Public education and marketing campaigns to encourage eco-driving and other smart transportation techniques are based on successful marketing methods including community based social marketing (McKenzie-Mohr 2011) and individualized marketing.

Existing research findings

- In general, at speeds from 35 to 45 miles per hour, if a vehicle reduces its speed by five mph, its fuel economy can increase by about five to ten percent; air resistance, or drag, increases exponentially as a vehicle goes faster. A driver could see fuel economy increase by 7 to 23 percent when observing speed limit and not exceeding 60 mph (where legally allowed). A few seconds of high-powered driving can use as much gas as driving for several minutes at more measured speeds (EcoDrivingUSA.com).

- Rapid starts and stops, often called “jack rabbit” starts and stops, wastes fuel. Gentle acceleration and braking can improve fuel economy by up to 33 percent (EcoDrivingUSA.com).
- Navigation systems featuring eco-routing have been shown to improve fuel economy up to 15 percent (US DOT 2010).
- Maintaining factory-specified tire pressure can improve gas mileage by 3 percent. Under-inflated tires can lower gas mileage by 0.3 percent for every 1.0 psi drop in pressure of all four tires. Experts estimate that 25 percent of automobiles are running on tires with lower than recommended pressure. (EcoDrivingUSA.com)
- A study in Southern California found that a combination of eco-driving training and on-board monitoring devices resulted in an average 6 percent increase in fuel economy for city driving and one percent increase in highway driving (Kanok, et al. 2010).
- The *Moving Cooler* study estimated a 19 percent increase in fuel economy if eco-driving practices are used.

Case Study: *Drive Less Save More* Campaign

The Metro Regional Travel Options (RTO) program applies a collaborative marketing strategy to accomplish public education and marketing across the Portland region as part of the Metro 2008-2013 RTO Strategic Plan. The RTO program coordinates marketing activities with regional partners and supports implementation of the *Drive Less Save More* campaign. Launched in February 2006, the campaign involves outreach at community events to engage the public in the campaign and to provide localized travel options information.

The goal is to raise public awareness about the benefits of driving less through trip chaining and other smart driving alternatives, such as riding transit, carpooling, vanpooling, ridesharing, telecommuting, biking and/or walking. Now in its fifth year, *Drive Less Save More* is becoming more effective. Research conducted in 2009 revealed:

- Though collaborative marketing requires staff time, it is cost-effective because regional partner efforts are coordinated across the region.
- Over the past several years, *Drive Less Save More* cost approximately $1 million per year, primarily for advertising, but was matched with another $1 million per year from news stories about the campaign, donated advertising and sponsor contributions.
- Nearly 19 percent of the region’s population - more than 222,000 individuals - have reduced car trips as a result of the campaign, resulting in a reduction of an estimated 21.8 million vehicle road miles and about 10,700 tons of CO_2.

Co-benefits and synergy with other strategies

Co-benefits

Beyond reducing GHG emissions, the education, marketing and commuter programs strategy has the potential to provide other important benefits to a community including:

Public health and safety benefits:

- Increased physical activity from walking and biking, leading to reduced risk of obesity, diabetes, heart disease and premature death
- Enhanced public safety; reduced risk of traffic injuries and fatalities
- Improved air quality and fewer air toxics emissions, leading to reduced risk of asthma, lung disease and premature death

Environmental benefits:

- Lower levels of pollution
- Less energy use

Economic benefits:

- Job opportunities
- Reduced fuel consumption; reduced reliance on foreign oil
- Consumer savings
- Increased cost effectiveness of transit investment through improved ridership

Synergies with other strategies

Synergy exists when a combination of two or more strategies enhances the potential GHG emissions reduction from an individual strategy. Education, marketing and commuter programs are synergistic with several other strategies including:

- Mixed-use development in centers and corridors
- Active transportation and complete streets
- Public transit service
- Tolls, fees, and insurance
- Individualized marketing
- Employer-based commute programs
- Traffic management
- Fleet mix and turnover
- Vehicle technology and fuels

Considerations moving forward

These strategies are relatively easy and inexpensive to implement, making them ideal near-term options for GHG reduction strategies. Eco-driving has been shown to yield measurable reductions in fuel consumption by maximizing vehicle operations. The research suggests that training motorists to use more efficient driving behaviors has a big effect on fuel usage and emissions.

Education can take on a variety of forms with different levels of scale and effort. Public education campaigns, such as *Drive Less Save More*, can be effective at broadcasting information at the local, regional and state levels; in fact, they've proven effective when operated by a variety of partners. Private businesses with fleets can realize an economic benefit by training their staff to use eco-driving behaviors and strategies.

A MARKETING AND INCENTIVES STRATEGY

Individualized Marketing (IM) is an outreach method where individuals or families interested in making changes in their travel behavior are identified to participate in a program. A combination of information and incentives is tailored to their specific travel needs to support behavioral changes. Before and after surveys are conducted to measure travel behavior changes resulting from marketing efforts.

- IM is an effective soft-policy approach that maximizes the use of existing transportation infrastructure such as bike lanes, sidewalks and transit systems.
- Reductions in car-driver trips from IM programs range between four and 19 percent; VMT decreases as a consequence.
- Travel behavior changes associated with IM programs are sustained for at least two-years and potentially longer.

Existing research findings

IM projects decrease GHG emissions by reducing the number of automobile trips undertaken by households. Trip-related reductions in GHG from IM projects range between four and 19 percent (Fuji and Taniguchi 2006; Sloman et al. 2010; WinSmart 2009). Results from the City of Portland's SmartTrips IM projects show an average 10 percent reduction in car-driver trips, which equates to an annual savings of approximately 19 million pounds of CO_2 (City of Portland 2009). This is equivalent to the CO2 emission from 1,690 cars or from electricity used by 1,075 homes.

Compared to investments in transportation infrastructure, IM programs are cost-effective because they maximize the use of the existing transportation system. Conservative calculations made for Perth, Australia IM projects show return on investment at a 30:1 ratio (Brög and John 2001).

The success of IM programs across Western Australia spurred the government to embark on a new IM methodology called LivingSmart. The LivingSmart projects provide interested households with information on a variety of sustainability topics such as energy conservation, recycling, water conservation and transportation options. LivingSmart projects show positive results in behavior change and associated GHG reductions.

Co-benefits and synergy with other strategies

Co-benefits

Beyond reducing VMT and GHG emissions, IM strategies have the potential to provide other important co-benefits to a community. Co-benefits include:

Public health and safety benefits:

- Increased physical activity from walking and biking, leading to reduced risk of obesity, diabetes, heart disease and mortality
- Enhanced public safety; reduced risk of traffic injuries and fatalities
- Improved air quality and fewer air toxics emissions, leading to reduced risk of asthma, lung disease and mortality

Environmental benefits:

- Lower levels of pollution
- Less energy use

Economic benefits:

- Increased access to jobs, goods and services
- Reduced fuel consumption; reduced reliance on foreign oil
- Consumer savings
- Increased cost effectiveness of transit investments through improved ridership

Synergies with other strategies

Synergy exists when a combination of two or more strategies enhances the potential GHG emissions reduction from an individual strategy. IM strategies are synergistic with several other strategies including:

- Mixed-use development in centers and transit corridors
- Active transportation and complete streets
- Public transit service
- Public education and marketing
- Vehicle technology and fuels

Case Studies – International individualized marketing examples

- After an IM project in Cambridge, Australia, the Public Transit Authority showed a net 25 percent increase in bus boardings over a 28-month period (John and Rampellini, 2004).
- A LivingSmart project targeting 10,000 households can abate approximately 12,000 metric tons of CO2 each year. Costs associated with LivingSmart projects are a little less than $200 US dollars per household (Peart and MacDonald, 2008)

Case Studies – Portland region individualized marketing examples

- An IM project improved transit ridership on a new light rail line along the Interstate corridor in Portland, Oregon. Transit trips increased at nearly double the rate among households compared to a control group. (Social data America, 2005).
- A SmartTrips project in Milwaukie, Oregon greatly increased awareness of the Springwater Corridor Trail. In the pre-survey only 11 percent had used the trail and over 54 percent couldn't answer because they were unaware that the trail existed. This is a key concept of the SmartTrips approach: residents will not take advantage of walking and bicycling amenities if they do not know they exist. With the intense outreach and education that occurred over one summer, use of the Springwater Corridor Trail increased significantly. Post-survey results show that 44 percent of respondents had used the trail within the year (a 300 percent increase) and only one of 260 respondents couldn't answer the question compared to 54 percent before the survey.

Considerations moving forward

Where to apply and scale of application

IM projects have the highest potential for success when targeted to neighborhoods with good access to transportation options and amenities. However, successful IM projects have also been implemented in suburban environments. Many transportation agencies have adopted IM programs because they are cost-effective, versatile and can be adapted to meet environmental and infrastructure challenges.

Potential timing and phasing of implementation

IM projects are highly effective when coupled with transportation system improvements and, therefore, this method is recommended when marketing new transportation projects to the public. IM projects should be implemented during the warmer months and the 'before' and 'after' travel surveys should be conducted during similar seasons, as weather can affect mode choice. A typical IM project would launch the 'before' survey in the spring, the marketing component in the summer/fall and the 'after' survey during the following spring. Research also recommends designating a control group within the household sample to ensure that travel behavior changes are the result of the IM program alone and not because of weather, system improvements, or outside marketing influences.

Who implements

IM programs are fairly easy to execute and numerous transportation agencies have adopted their own versions to meet local conditions and budget constraints. Originally developed by Social Data, more consulting firms now support IM projects.

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A MARKETING AND INCENTIVES STRATEGY

Employer-Based Commuter Programs are work-based travel demand management programs; they can help reduce single occupancy vehicle trips by providing employees with incentives, information, and additional transportation options. Commuter travel is largely responsible for peak period congestion twice a day during weekdays. Shifting the mode of travel and time of travel for these trips has the potential to reduce VMT and carbon emissions, alleviate congestion during peak periods, and improve air quality. Examples of employer-based commuter programs are listed below.

Financial incentives:

- Transit pass programs
- Cash and merchandise
- Tax incentives (both business and individual)
- Parking pricing/cash-out, which allows employees to opt out of having a subsidized parking space and instead receive compensation

Facilities and services:

- Transportation coordinators
- Ride-matching and carpooling programs
- End-of-trip facilities (bike parking, showers, lockers, etc.)
- Guaranteed ride home (set amount of free taxi rides or car-share trips in the event of an emergency)
- Events and competitions

Flexible scheduling:

- Telecommuting
- Compressed or flexible work weeks

Methods of program delivery include:

- an employer-supported program, where the employer plays a direct role in funding or sponsoring strategies; or,

- an individualized marketing approach, where an outside party is granted permission to contact employees directly and provide information and incentives to reduce their auto trips (see previous section on Individualized Marketing).

This strategy section focuses primarily on employer-supported programs, such as the Employee Commute Options (ECO) program. Employers in the Portland metropolitan region with more than 100 employees at a given worksite must show a good faith effort towards reducing drive-alone commute trips by 10 percent from an established baseline. Businesses affected by Employee Commute Options must survey their employees every two years to measure progress towards the goal, and create a plan that delineates the steps they will take in pursuit of the 10 percent reduction.

According to the most recent Metro Regional Travel Options (RTO) Program Evaluation, there are more than 1,100 worksites in the Portland region with employer transportation programs. The most comprehensive data comes from commute surveys of employees at worksites that participate in outreach programs offered by TriMet. All of the RTO evaluations have used these data as a benchmark for measuring program efficiency, dating back to 1996. The overall trend shows that multiple-driver trips are increasing at companies participating in these programs.

Existing research findings

Employer-based strategies were found to reduce employee trips as follows:

- 20 to 30 percent by charging for parking,
- 1.4 percent by providing information only,
- 8.5 percent by providing services like carpooling only,
- Eight to 18 percent by providing financial incentives only,
- 24.5 percent by providing both services and financial incentives, and
- 17 percent by providing a cash-out program (Seattle DOT 2008).

Other research has documented reductions in VMT and GHG emissions reductions:

- 12 percent VMT reduction for individuals participating in parking cash-out programs in California (Shoup 1997)
- Two to 3 percent reduction in VMT when charging $3 per day for workplace parking (Deakin et al. 1996)
- 0.1 to 19.7 percent commute trip VMT reduction, depending on the rate charged per day for workplace parking (CAPCOA 2010)
- 0.7 to 5.5 percent commute trip reduction when telecommuting and alternative work schedules are encouraged, depending on the level of participation (Cambridge Systematics 2009)

- 0.3 to 13.3 percent commute trip reduction when employers provided vanpools or shuttles to transit stations or commercial centers (Evans, J.E., et al. 2005).

Overall, unbundling parking costs from property costs is an effective strategy and removes the burden from those who do not need a parking space. When parking is priced separately and instead borne by the user it results in a 2.6 to 13 percent GHG emissions reduction (CAPCOA 2010).

Since commute trip reduction programs bundle strategies, a greater reduction of VMT and GHG emissions can be realized. Similar to Oregon's ECO program, employers in the state of Washington that have 100 or more full-time employees are required to implement a Commute Trip Reduction (CTR) program. Research conducted using the Washington State CTR database provides detailed information on commuter strategies implemented by the employer, worksite characteristics and employees' travel behavior, and their job related characteristics. The CTR database tracked more than 1,000 worksites and about 300,000 individual employees from 1993 to 2005.

The data indicates that, for the employees affected by the program between 1993 and 2005, the participation rates of compressed work weeks increased steadily from 14.5 percent in 1993 to 20 percent in 2005 (Zhou 2011). The drive alone rate among targeted employers was reduced from 81.8 percent in 1993 to 72.5 percent in 2011. Additionally, carpooling has seen the largest increase in use compared to other travel options with a mode share increase from 10.5 percent in 1993 to 14.4 percent in 2011. The Washington State CTR Program removes 20,700 vehicles from the road on a daily basis. This results in a reduction of nearly 3,700 tons of GHG emissions each year (Pierce County 2010). This evaluation focused on one employee-based strategy and may underestimate the participation rate when taking into account the range of employer-based programs available at an individual worksite—parking cash out, telecommuting, transit passes, etc.

Related research on commute trip reduction programs has found that voluntary programs can result in a 1 to 6 percent reduction in commute trip VMT, but that a required and monitored program can result in a 4.2 to 21 percent reduction (CAPCOA 2010).

Case Study: Commute Trip Reduction in King County, Washington

In King County, Washington, an Employer Transportation Representative assists Commute Trip Reduction-affected companies in the region with programming, goal setting, and mode split measurement. Surveys have found that companies affected by Commute Trip Reduction made 14,200 fewer vehicle trips each day in 2005 compared to 1993, which equates to an estimated 11.6 percent in reduced peak travel delay (Seattle DOT 2008).

Co-benefits and synergy with other strategies

Co-benefits

Beyond reducing VMT and GHG emissions, employer-based commuter program strategies have the potential to provide other important co-benefits to a community. Co-benefits include:

Public health and safety benefits:

- Increased physical activity from walking and biking, leading to reduced risk of obesity, diabetes, heart disease and premature death
- Improved air quality and fewer air toxics emissions, leading to reduced risk of asthma, lung disease and premature death

Environmental benefits:

- Lower levels of pollution
- Less energy used

Economic benefits:

- Increased access to jobs, goods and services
- Reduced fuel consumption; reduced reliance on foreign oil
- Consumer savings
- Increased cost effectiveness of transit investment through improved ridership

Synergies with other strategies

Synergy exists when a combination of two or more strategies enhances the potential GHG emissions reduction from an individual strategy. Employer-based commuter program strategies are synergistic with several other strategies including:

- Mixed-use development in centers and corridors
- Active transportation and complete streets
- Public transit service
- Parking pricing
- Tolls, fees and insurance
- Public education and marketing

Considerations moving forward

While transit continues to account for a significant share of commute trips among businesses participating in these programs, its share has been in a slight decline since 2006. This can be attributed in part to economic factors, like fewer jobs and declining revenue to track these programs.

Ridesharing is still widely used, representing 8.5 percent of commute trips in the 2008 evaluation, but has been steadily declining in popularity since 1996. Additionally, it is unclear how many carpools are actually comprised of two or more co-workers that reduce auto trips. National studies show that 75 to 80 percent of so-called "carpools" are actually "fampools", involving transporting children or adults living in the same home traveling together (McGuckin and Srinivasan).

This same time period, however, saw growth in the use of a compressed work week and telecommuting, as well as in bicycling and walking. Bicycling and walking offer much promise for growth as the trend of people living closer to their worksite continues. Active transportation and public transit service outreach efforts, in this case through employer-based commuter programs, must be relevant to a range of communities and income levels. Campaigns must ensure relevancy to a diverse range of community perspectives. One example is Metro's RTO program, which provides programs for Spanish-speaking populations.

Where to apply and scale of application

Two primary factors should be evaluated when considering this strategy: The relative availability of transit and active transportation infrastructure; and the presence of local partners (such as Transportation Management Associations or business associations) to help implement and promote programs. Without these factors, employers are much less likely to implement meaningful trip-reduction measures.

Potential timing and phasing of implementation

It should be noted that there is likely a leveraging factor associated with initiating these programs in conjunction with the opening of new infrastructure, such as new transit service or bike and pedestrian facilities.

Who implements

Programs should be coordinated at a regional and state level, but implemented at the local level. Programs led by cities or Transportation Management Associations have traditionally generated the best results.

The Metro RTO program, for example, works with employers to develop and implement relevant strategies to reduce drive-alone commute trips. In addition to working with the employer, Metro involves external partners, such as Transportation Management Associations, TriMet, and the City of Portland.

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Management Strategies

Traffic and Incident Management

Management strategies use intelligent transportation systems (ITS) to help traffic move more efficiently and smoothly. These tools increase vehicle flow and system efficiency, reducing the rapid acceleration, deceleration and idling associated with congestion. They also reduce vehicle emissions, improve safety and restore traffic patterns to an efficient state. The individual management strategies (ramp metering, active traffic management, traffic signal coordination and traveler information) complement each other, and when implemented together, they have a greater potential for reducing GHG emissions. The potential reductions highlighted below are not additive and vary depending on the combination of strategies implemented.

TRAFFIC MANAGEMENT

Ramp metering: Use traffic signals at freeway on-ramps to regulate the rate of vehicles entering the freeway.

Active traffic management: Use signs to share variable speed limits and real-time traffic information to maximize the efficiency of a specific roadway.

Traffic signal coordination: Time traffic signals to improve vehicle speeds and flow to reduce delay at intersections.

Traveler information: Use signs, the Internet, or phone services to update drivers with real-time traffic information.

1 to 2 percent
Reduction in GHG emissions if national speed limits were reduced to 55 mph

75,000 gallons
Annual fuel savings estimated from implementation of an adaptive signal system in the city of Gresham, Oregon

169,000 tons
Annual CO_2 reduction after Portland retimed 150 signalized intersections—equal to taking 30,000 cars off the road

TRAFFIC INCIDENT MANAGEMENT

Traffic incident management: A coordinated process to detect, respond to, and remove traffic incidents from the roadway as safely and quickly as possible, reducing non-recurring roadway congestion.

CO-BENEFITS

Public health and safety benefits

- increased physical activity from walking and biking, leading to reduced risk of obesity, diabetes, heart disease and premature death
- enhanced public safety; reduced risk of traffic injuries and fatalities
- improved air quality and fewer air toxics emissions, leading to reduced risk of asthma, lung disease and premature death

Environmental benefits

- lower levels of pollution
- less energy use

Economic benefits

- consumer savings
- increased access to jobs, goods and services
- reduced fuel consumption; reduced reliance on foreign oil
- business savings

SYNERGY WITH OTHER STRATEGIES

- mixed-use development in centers and corridors
- public transit service
- parking pricing
- tolls, fees and insurance
- public education and marketing

IMPLEMENTATION

This suite of management strategies can be implemented by local, regional or state agencies. In order for these strategies to have the desired effects of improving traffic flow, reducing emissions and improving safety, it is important for investments and systems to be coordinated throughout the region. The Portland region has had an incident management program in place since 1997 that has continued to improve incident detection, response time, and clearance time through added staff and vehicles, ITS equipment coverage, and Transportation Management Operations Center upgrades. Since 2005, Metro has actively managed regional coordination and integration of these strategies through TransPORT, a regional committee led by Metro in partnership with staff from cities, counties, TriMet, the Oregon Department of Transportation and other transportation system providers.

Traffic management uses intelligent transportation systems (ITS) to help traffic flow move efficiently and smoothly. These tools serve to increase vehicle flow, reducing acceleration, deceleration and idling associated with congestion. They also improve safety and restore traffic patterns to an efficient state. There are numerous management strategies that have been deployed across the U.S., including:

Ramp Metering

The use of traffic signals at on-ramps to regulate the rate of vehicles entering the freeway.

Active Traffic Management

Managing traffic in response to prevailing traffic conditions in order to maximize the efficiency of a specific roadway. Active Traffic Management (ATM) uses variable messages to display variable speed limits, queue warnings, and land control on overhead signs.

Electronic message boards are installed on two interstates and one highway in Washington that display variable speed limits, land status and real-time traffic information. Benefits include improved safety through the reduction of collisions and increased roadway capacity through reduced congestion (Washington DOT 2009).

Traffic Signal Coordination

Communication between traffic signals on the timing of red and green lights to even out vehicle speeds, improve vehicle throughput and reduce delay at intersections.

Traveler Information

By using variable message signs, the internet, or 511 phone services, up-to-date information can be provided to travelers regarding traffic conditions, incidents, delays, travel times, alternate routes, weather conditions, construction, or special events.

Existing Research Findings

Ramp Metering

Studies have shown that regulating the flow of vehicles entering a freeway can yield GHG reductions of 0.04 to 0.12 percent by 2050 (Cambridge Systematics 2009). In 2001, Minneapolis shut down ramp meters on freeways for a six-week evaluation period. The results of the evaluation indicated that without ramp metering there would be an increase in vehicle emissions of 1,160 tons, which is equivalent to adding 206 cars to the road.

Active Traffic Management

There is a limited amount of research on ATM as it relates to GHG emissions. The research that is available indicates that ATM can yield GHG reductions of up to 0.12 percent by 2050 (Cambridge Systematics 2009). Studies have also shown that reducing national speed limits to 55 miles per hour could yield GHG reductions of 1.2 to 2 percent (U.S. DOT 2010). Deploying variable speed limits with proper enforcement could work to achieve a similar outcome.

Signal Coordination

Reducing delay associated with stop and go traffic through signal timing has been shown to decrease fuel consumption and GHG emissions. The adaptive signal system in the city of Gresham, Oregon is estimated to save 75,000 gallons of fuel per year (DKS Associates 2008). The City of Portland retimed 150 signalized intersections in 2005, estimating an annual reduction in CO_2 emissions of 169,000 tons (Metro, Traffic Signal Coordination).

Traveler Information

Research has calculated the impacts of providing traveler information. One potential effect is that it can help reduce emissions by improving traffic flow and reducing congestion. However, improving traffic flow can also encourage more driving through greater (induced) travel demand, thereby negating any reduction in emissions. When not taking induced demand into account, providing travel information can reduce GHG emissions by less than one percent (Cambridge Systematics 2009).

Operations Management for Delivery Vehicles

Operations of light delivery trucks (less than 10,000 pounds) should be considered in GHG emissions reduction strategies. Trucks on delivery routes can add congestion and additional VMT to the road system if they are:

1) Not packed to an optimum load
2) Out on deliveries even when the recipient isn't at work or home
3) Not following an optimized route
4) Operating during peak congestion periods

During the 2008 holiday season, UPS hired eight employees to delivery 25-50 packages per day by bike in the Portland metro area (a truck delivers 150 packages per day). For every three bikes, UPS saved 17 gallons of fuel per day, which equates to $50 in savings (Maus 2008).

From the local or regional level, elected officials can work with the business community to maximize efficiency in deliveries, whether providing consistent signage, maps, or changing routes.

Adopting operations management practices that allow vehicles to operate on more optimized routes, during off-peak hours, or by bicycle offers several co-benefits to the community: increased physical activity from walking and biking, lower levels of pollution, improved air quality as a result of reduced traffic congestion, reduced fuel consumption, and business savings in transportation.

Case Studies: Traffic management examples from the Portland region

The Portland region has successfully employed a variety of traffic management strategies. Gresham's adaptive signal control system has been a successful model for reducing travel times as well as annual fuel consumption. Ramp meters on regional freeways help improve traffic flows. Active traffic management has not been fully implemented in the Portland region, though the recent deployment on I-5 in Seattle may prove a successful model pending more conclusive documented impacts.

Co-benefits and synergy with other strategies

Co-benefits

Beyond reducing VMT and GHG emissions, traffic management strategies have the potential to provide other important co-benefits to a community. Co-benefits include:

Public health and safety benefits:

- Enhanced public safety; reduced risk of traffic injuries and fatalities
- Improved air quality and fewer air toxics emissions, leading to reduced risk of asthma, lung disease and premature death

Environmental benefits:

- Lower levels of pollution
- Less energy used

Economic benefits:

- Consumer savings
- Reduced fuel consumption; reduced reliance on foreign oil

Synergies with other strategies

Synergy exists when a combination of two or more strategies enhances the potential GHG emissions reduction from an individual strategy. Traffic management strategies are synergistic with several other strategies including:

- Mixed-use development in centers and corridors
- Public transit service
- Parking pricing
- Tolls, fees, and insurance
- Public education and marketing
- Traffic incident management

Considerations moving forward

While individual traffic management strategies do not have a substantial impact on GHG emissions reductions, when implemented in combination with one another they have greater potential for such reductions. Traffic management strategies are well suited for implementation by local, regional, or state agencies. In order for these strategies to have the desired effect of improving traffic flow, reducing emissions, and improving safety, it is important for investments and systems to be coordinated throughout the region. Since 2005, Metro has actively managed regional coordination and integration of these strategies through TransPORT, a regional committee led by Metro in partnership with staff from cities, counties, TriMet, the Oregon Department of Transportation and other transportation system providers.

Traffic Incident Management (TIM) is a planned and coordinated process by multiple public agencies and private sector partners to detect, respond to, and remove traffic incidents and restore traffic operations as safely and quickly as possible. The primary goals of TIM programs are to reduce non-recurring roadway congestion and secondary incidents. Traditionally, emissions reduction has been seen as a secondary benefit.

Nationally, traffic incidents account for 40 to 50 percent of all non-recurring congestion on roads. Lane-blocking incidents affect traffic flow far out of proportion to the number of lanes blocked. An incident blocking one lane out of three on a freeway reduces the capacity of that facility by approximately 50 percent. Blocking two lanes of three reduces capacity by nearly 80 percent. It is estimated that every one minute of traffic incident duration adds four minutes of traffic delay, meaning that congestion continues long after an incident is cleared. The link between traffic incident management programs and reduced vehicle emissions is travel delay reduction.

Existing research findings

A 2011 literature review of incident management programs completed for the California Air Resources Board found five studies dating back to 1995 on the effects of TIM programs on vehicle criteria pollutants emissions. While the studies did not look at CO_2 emissions specifically, GHG reduction can be inferred from findings that levels of hydrocarbons (HC), carbon monoxide (CO) and nitrogen oxide (NOx) declined as traffic delay was reduced.

Table 4 highlights selected studies that examined incident response programs in urban areas during congested time periods. The researchers surmised that urban areas, particularly central locations lacking breakdown lanes, would have the greatest benefit from TIM programs. Types of studies include: Freeway Service Program (FSP), the NaviGAtor regional system study, and a highway segments study. The study years range from 1993 to 2005 (Boarnet, et al. 2011).

Table 4. Comparison of incident response program studies

Study type and location	Incident Delay Reduction	HC reduction per incident (kg)	CO reduction per incident (kg)	NOx reduction per incident (kg)
FSP- Alameda County, CA	Response time for FSP-assisted breakdowns reduced delay by 12.6 minutes (57%)	3.51	35.84	8.85
FSP- LA County, CA	Incidents without FSP-assistance lasted 7-20 minutes longer (35%)	1.46	11.51	2.97
NaviGAtor-Atlanta, GA	N/A	5.775	75.58	8.059
C.H.A.R.T.- DC and Baltimore	C.H.A.R.T. reduced average incident induced travel delay by 21.9 minutes (43%)	24	269.75	11.48
Highway segments- Bay Area, CA	N/A	N/A	1219	260.79

Co-benefits and synergy with other strategies

Co-benefits

Beyond reducing VMT and GHG emissions, traffic incident management strategies have the potential to provide other important co-benefits to a community. Co-benefits include:

Public health and safety benefits:

- Enhanced public safety; reduced risk of traffic injuries and fatalities
- Improved air quality and fewer air toxics emissions, leading to reduced risk of asthma, lung disease and premature death

Environmental benefits:

- Lower levels of pollution
- Less energy used

Economic benefits:

- Increased access to jobs, goods and services
- Consumer savings in transportation
- Reduced fuel consumption; reduce reliance on foreign oil
- Business savings from reduced travel delay

Synergies with other strategies

Synergy exists when a combination of two or more strategies enhances the potential GHG emissions reduction from an individual strategy. Traffic incident management strategies are synergistic with traffic management strategies.

Pre-trip and in-route traveler information naturally complement TIM by disseminating information about travel conditions to influence route choice and the timing of trips. Intelligent Transportation System (ITS) devices also support TIM. For example, when a breakdown causes traffic to slow down, the traffic sensors in the pavement detect the change and alert an operations dispatch center. An operator can then use a CCTV camera to verify that an incident has occurred and determine the appropriate response. Information about the incident can be posted on roadside signs to alert other drivers.

Considerations moving forward

TIM programs are primarily initiated in response to congestion and safety concerns. More evaluation needs to be done on its benefits for GHG reduction before a definitive link can be made. However, there is evidence of positive effects on traffic delay due to reduction in incident duration, which can indirectly be tied to GHG emissions reductions.

The Portland region has had a robust incident management program in place since 1997 that has continued to improve incident detection, response time, and clearance time through added staff and vehicles, ITS equipment coverage, and Transportation Management Operations Center upgrades. Since 2005, Metro has actively managed regional coordination and integration of these strategies through TransPORT, a regional committee led by Metro in partnership with staff from cities, counties, TriMet, the Oregon Department of Transportation and other transportation system providers.

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Fleet and Technology Strategies

Fleet Mix, Turnover, Technology, and Fuels

The proportion of vehicles on the road with improved fuel technology is a major determinant of GHG emissions per mile of travel. The individual strategies complement each other, and when implemented together, they have a greater potential for reducing GHG emissions. The potential reductions highlighted below are not additive and vary depending on the combination of strategies implemented.

FLEET MIX AND TURNOVER

Fleet mix: The percentage of vehicles classified as automobiles compared to the percentage classified as light trucks (weighing less than 10,000 lbs.); light trucks make up 43% of the light-duty fleet today.

Fleet turnover: The rate of vehicle replacement or the turnover of older vehicles to newer vehicles; the current turnover rate in Oregon is 10 years.

58 percent

Improvement in average fuel economy of vehicles sold under the C.A.R.S. rebate program

0.6 to 1.4 million tons

CO_2 reduction projected annually if 60,000 trucks were replaced with hybrid trucks; equal to taking 249,000 cars off the road nationally

VEHICLE TECHNOLOGY AND FUELS

Fuel economy: Fuel economy standards are expected to strengthen at both the federal and state levels in the future. The Federal C.A.F.E. standards culminate in a fleet-wide average of 35.5 mpg by 2016, and a proposed standard of 54.5 mpg by 2025.

Carbon intensity of fuels: This strategy is usually regulated through low carbon fuel standards, which encourage higher adoption rates of alternative fuel vehicles and more production of lower carbon fuels.

Electric vehicles, hybrids and plug-in hybrids: Electric vehicles are battery powered only; hybrids are a combination of gas and electric powered; plug-in hybrids are hybrids that can be charged at an electrical outlet.

19 percent

Reduction in GHG emissions from light-duty vehicles by 2030 if a 35.5 miles per gallon fleet-wide average is achieved by 2016

25 percent

Reduction in CO_2 per mile from a plug-in hybrid powered by an old coal plant versus a conventional gasoline vehicle

.5 to 13 percent

Reduction in VMT from deployment of neighborhood electric vehicles

.4 to 20 percent

Reduction in GHG emissions from deployment of electric or hybrid vehicles

CO-BENEFITS

Public health and safety benefits

- improved air quality and fewer air toxics emissions, leading to reduced risk of asthma, lung disease and premature death

Environmental benefits

- lower levels of pollution
- less energy use

Economic benefits

- job opportunities
- leverage private investments
- reduced fuel consumption; reduced reliance on foreign oil
- consumer savings
- increased energy security

SYNERGY WITH OTHER STRATEGIES

- mixed-use development in centers and corridors
- public transit service
- public education and marketing
- individualized marketing

IMPLEMENTATION

Much work is being done at the state and federal levels to expand the number of vehicles with higher fuel efficiency and lower emissions, and to reduce the carbon content of fuels. Pilot projects and other policies can be implemented at the local and regional levels to support these efforts.

Policies include developing a reliable network of public and private electric vehicle charging stations and supportive infrastructure, providing consumer and businesses incentives to make the higher initial purchasing costs of hybrid and electric vehicles more affordable, government and corporate purchases to increase visibility, supportive permitting and codes for vehicle charging stations and public education. Anxiety related to distances between charging stations are among the issues that need to be addressed.

Fleet mix refers to the percentage of vehicles classified as automobiles compared to light trucks, which include delivery vehicles (weighing less than 10,000 lbs.), sport utility vehicles and pick-up trucks. This distinction is important given significant differences in auto and light truck fuel economy.

It is particularly relevant in Oregon, where there is a relatively high percentage of vehicles classified as light trucks. Light truck vehicle proportions, compared to auto proportions, increased from 30 to 43 percent between 1990 and 2005 in Oregon. Shown in Table 5, the Metropolitan Greenhouse Gas Emissions Reduction Target for the Portland region assumes the light truck proportion will decline to represent 29 percent of the overall light-vehicle fleet by 2035.

Fleet turnover refers to the rate of vehicle replacement or the turnover of older vehicles to newer vehicles. The current fleet turnover rate in Oregon is ten years. Shown in Table 5, the Metropolitan Greenhouse Gas Emissions Reduction Target for the Portland region assumes a turnover rate of eight years by 2035. Newer vehicles are typically more fuel efficient than older vehicles, and thus newer fleets are assumed to yield greater GHG emissions reductions.

Technical data for GHG emissions reductions regarding fleet mix and turnover was published in the *Agencies' Technical Report*, which was completed in March 2011 by ODOT, the Oregon Department of Environmental Quality, and the Oregon Department of Energy. The region's GHG reduction target is based on this report and was adopted by LCDC in May 2011. The state assumptions for fleet mix and turnover are highlighted in **Table 5**.

Table 5. Baseline Assumptions for Vehicle Fleet in Oregon

Characteristic	1990	2005	2035
Light trucks as a percentage of overall fleet mix	30%	43%	29%
Average vehicle replacement rate	10 years	10 years	8 years

Existing research findings

A report by the Electric Power Research Institute and the Natural Resources Defense Council found that if 60 percent of light duty vehicles were powered by our current electric grid instead of gasoline, GHG emissions from this sector would be reduced by one-third. Another report projected that putting 60,000 hybrid trucks on the road would reduce CO_2 emissions between 0.6 and 1.4 million tons per year (EDTA 2011).

Caveats on research

Although a faster turnover rate of eight years for overall fleet may yield greater fuel efficiency and savings for consumers, this assumption does not include the consideration of GHG emissions related to the production of new vehicles, which is an external cost not accounted for in the state GHG reduction target. In addition, another consideration is the rebound effect, whereby the improved fuel economy that could come from transitioning from a light-duty truck to a automobile could encourage additional VMT. It is important to consider which of the various strategies outlined in the Toolbox will be most effective at reducing GHG emissions.

Co-benefits and synergy with other strategies

Co-benefits

Beyond reducing VMT and GHG emissions, changes to fleet mix and vehicle turnover strategies have the potential to provide other important co-benefits to a community. Co-benefits include:

Public health benefits:

- Improved air quality and fewer air toxics emissions, leading to reduced risk of asthma, lung disease and premature death

Environmental benefits:

- Lower levels of pollution
- Less energy use

Economic benefits:

- Job opportunities
- Leverage private investments
- Reduced fuel consumption; reduced reliance on foreign oil
- Consumer savings
- Increased energy security

Synergies with other strategies

Synergy exists when a combination of two or more strategies enhances the potential GHG emissions reduction from an individual strategy. Changes to fleet mix and vehicle turnover strategies are synergistic with several other strategies including:

- Mixed-use development in centers and corridors
- Public transit service
- Public education and marketing

- Vehicle fuels and technology

Fleet mix and turnover is synergistic with mixed-use development because of the potential to serve the needs of lower-income households.

Considerations moving forward

Fleet strategies are best implemented at the state and federal levels because of the large scale and scope required for such policies. There are, however, policies that can be implemented at local and regional scales that complement state efforts in order to yield a higher rate of fleet turnover. One approach is for local governments to turn their own vehicle fleets over; localities can kick start the trend and also act as an example for businesses and individuals.

It will also be important to recognize that lower income individuals and families are less likely to have a car and more likely to own older cars when they do (Murakami 1997). Programs that get people into more fuel efficient vehicles or utilizing other modes of transportation will help get older, inefficient vehicles off the road. Furthermore, integrating affordable housing choices with mixed-use development will ensure that lower-income households can be less reliant on personal vehicles and have access to transit, biking, and walking to meet their daily needs.

Case Study: Car Allowance Rebate System

During late 2009, the federal government offered the Car Allowance Rebate System (C.A.R.S.) to stimulate the economy while encouraging fleet turnover to safer and more fuel-efficient vehicles. The program was a success with respect to fuel economy. Under C.A.R.S., 85 percent of the trade-ins were light-duty trucks, and 59 percent of the new vehicle purchases were cars. The cars purchased under the program had a higher average fuel economy compared to other cars on the market at the time.

Additionally, the average fuel economy of new vehicles over trade-in vehicles resulted in a 9.2 mpg increase, or a 58 percent improvement (C.A.R.S. 2009). Another study found that during the C.A.R.S. program period, the fuel economy of all cars sold in the U.S. improved by 0.6 percent over the expected trajectory (Sivak and Schoettle 2009).

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There are a variety of strategies, vehicle technologies and fuels available to reduce GHG emissions including development of higher fuel economy standards, lowering the carbon content of fuels and deployment of electric vehicles and plug-in hybrids. The GHG emissions reduction potential of this strategy is directly related to the pace at which these strategies are implemented over time, and the types, convenience and affordability of vehicle technologies and supporting infrastructure made available to consumers and businesses.

Technical data for GHG reductions from vehicle technology and fuels was published in the *Agencies' Technical Report*. The region's GHG reduction target is based on this report, which was adopted by LCDC in May 2011. The state assumptions for vehicle technology and fuels and are highlighted in **Table 6**.

Table 6. Baseline Assumptions for Vehicle Technology and Fuels in Oregon

Characteristic	1990	2005	2035
FUEL ECONOMY			
Autos with internal combustion engine	28 mpg	28 mpg	68 mpg
Light trucks with internal combustion engine	20 mpg	20 mpg	48 mpg
Auto plug-in hybrids in charge sustaining mode	--	--	81 mpg
Light truck plug-in hybrids in charge sustaining mode	--	--	56 mpg
MARKET SHARE OF PLUG-IN HYBRIDS* OR ELECTRIC VEHICLES**			
Autos	--	--	8%
Light trucks	--	--	2%
CARBON IN FUELS			
Reduction in fuel carbon intensity from current levels	--	--	20%

*Assumed battery range of 35 miles for plug-in hybrids

**Assumed battery range of 175 miles for electric vehicles

Fuel economy

The fuel economy standards are expected to continue to be strengthened through the year 2035 at both the federal and state levels. At the federal level, the Corporate Average Fuel Economy (CAFE) will culminate in a fleet-wide average of 35.5 mpg by 2016, with a proposed standard of 54.5 mpg by 2025. Although an official number for long-term fuel standards isn't expected until November 2011, it is reasonable to assume that federal and Oregon state ambitions will be closely aligned. Oregon has adopted the California standards, which are still stronger than the federal fuel economy standards. The proposed 2035 fuel economy target rates for the Portland metropolitan region are highlighted in Table 6. The rates are 68 mpg for autos with internal combustion engines and 81 mpg for plug-in hybrid autos in charge sustaining mode.

Carbon intensity of fuels

In 2009, the Oregon legislature authorized the Environmental Quality Commission to develop low carbon fuel standards (LCFS) for Oregon. The goal is to reduce the average carbon intensity of Oregon's transportation fuels by 10 percent by 2022. Carbon intensity refers to the emissions per unit of fuel; it is not a cap on total emissions or a limit on the amount of fuel that can be burned. Carbon intensity encompasses emissions from extraction (growing in the case of biofuels), refinement, distribution, and combustion of a fuel – a true life cycle analysis approach.

Each type of transportation fuel (gasoline, diesel, natural gas, etc.) contains carbon in various amounts. This is also known as the "carbon content" of a fuel. When the fuel is burned, that carbon turns into carbon dioxide (CO2), which is a greenhouse gases. The lower the carbon content of a fuel, the fewer greenhouse gas emissions it produces. Extracting or growing the raw materials to make fuel, refining, transporting, and storing it also produces greenhouse gases. The sum of all the greenhouse gases emitted throughout the lifecycle of the fuel is called its "carbon intensity."

The Department of Environmental Quality's proposed LCFS provides incentives that encourage higher adoption rates of alternative fuel vehicles, more production of lower carbon fuels, and installation of more electric vehicle charging and alternative fuel dispensing equipment. Though the proposed standards not mandate the use of any specific fuel or combination of fuels, a mix of diesel, biodiesel, gasoline, ethanol, natural gas, and electricity is anticipated (Oregon DEQ 2011). Furthermore, the proposed standards do not regulate the public or individual gas stations. Finally, not every gallon of fuel needs to be 10 percent lower carbon emissions; rather the entire mix of fuel available needs to have 10 percent lower carbon emissions. Oregon could also join other West Coast states to create a low-carbon fuels corridor, as California has adopted a Low Carbon Fuel Standard and Washington is considering similar legislation (Oregon Environmental Council).

Electric vehicles and plug-in hybrids

A hybrid electric vehicle uses both an electric motor and an internal combustion engine or microturbine to propel the vehicle. The battery in a hybrid is designed to capture energy that is normally lost through breaking and coasting and in turn powers the electric motor. In 2010, hybrids represented nine of the ten most fuel efficient vehicles available in the US.

A plug-in electric vehicle is propelled by a battery that is charged at an electrical outlet. Three vehicle types make up this category:

- Plug-in hybrid vehicles are similar to conventional hybrids but their batteries can be charged. The range of travel in a plug-in hybrid varies depending on the battery size.
- Extended-range electric vehicles are propelled by electricity, with an internal combustion engine or other energy source that acts as a backup generator after the battery has discharged in order to extend the driving range of the vehicle.
- All-battery electric vehicles are propelled by electricity only (EDTA 2011).

Although hybrid electric vehicles consisted of just 3 percent of total vehicle sales in the US in 2008 (Electrification Coalition 2009), they are more popular in the Portland metropolitan area per household than any other city. In 2008, 11.1 new hybrids were sold per 1,000 households, with a US metro area average of 1.8. In 2009, that number of new hybrids sold in Portland dropped to 8.8, but Portland still maintained its position at the top of the chart (HybridCARS 2008). This illustrates that the market in Portland is ripe for the deployment of plug-in hybrids, and that related local and state incentives have great potential for reducing CO_2 emissions.

Case Study: I-5 West Coast Green Highway

The West Coast Green Highway initiative by Washington, Oregon, California, and the province of British Columbia is intended to advance the use of electric vehicles along Interstate 5. The initiative is currently supporting several projects, two of which include:

- The Alternative Fuels Corridor pilot project, which is still in concept phase, would provide evenly-space alternative fueling stations throughout the I-5 corridor. In Washington State, municipalities along I-5 with populations greater than 20,000 were required to provide electric vehicle infrastructure by 2010, and all other municipalities were required to allow electric vehicle infrastructure by 2011.
- New Mobility Hubs, which offer traffic information, rideshare matching, electric vehicle charging stations, bicycle storage, information for cyclists and transit riders, and tolling and transit card purchase kiosks. Washington DOT has plans to locate the first hub along State Route 520.

The market for electric vehicles in Portland is also likely to grow with help from federal initiatives like “One Million Electric Vehicles by 2015”. Under the plan, and in addition to increases in fuel economy standards, the federal government is working to increase electric vehicle sales to 1.7 percent of the total. Through the Recovery Act, investments have already been made to advance lithium-ion battery technology, support electric vehicle demonstration and deployment efforts, and incentivize the purchase of electric vehicles as well as conversion kits for conventional vehicles.

Another vehicle that is also growing in popularity is the Neighborhood Electric Vehicle (NEV). Resembling golf carts in size and speed, these smaller vehicles are seen as an alternative to taking neighborhood trips in less efficient traditional vehicles. The adoption of NEV's, also called microtransit, can be encouraged with the implementation of charging and parking infrastructure, creating connections between destinations and public transit, and funding for NEV start-up companies (Nisenson 2011).

Existing research findings

Fuel economy

The US Department of Energy estimates that a car averaging 15 mpg emits 12.2 tons of CO_2 annually (based on 15,000 annual miles); a car averaging 45 mpg emits 4.1 tons of CO_2 annually. Under the CAFE standard of fleet-wide average of 35.5 mpg by 2016, analyses project a GHG emissions reduction of 19 percent from light duty vehicles by 2030. Over the life of the program, the standards could reduce GHG emissions nationwide by approximately 900 million metric tons (US EPA 2009).

Case Study: Proposed Fuel Standards in California

In order for California to meet its 80 percent GHG emissions reduction goal by 2050, and to address environmental problems, the California Air Resources Board is proposing the adoption of the Advanced Clean Vehicles Program. The standards include reducing pollutants and greenhouse gases as well as working to increase the market share of Zero Emissions Vehicles (ultra-low carbon emissions and fuels) and clean fuels outlets and charging stations. This program would be instituted by amending California's Low-Emission Vehicle regulations alongside a push for adoption as a nationwide program (Cackette 2010). Development of informal regulatory documents continued throughout summer of 2011.

Carbon intensity of fuels

There is very little research on the GHG reduction potential of policies like low carbon fuels standards. Oregon-specific research conducted by DEQ shows that without the LCFS, the state's ability to reduce its GHG emissions from transportation will be even harder. As directed by House Bill 2186, DEQ commissioned an independent study to identify and estimate the potential economic impacts of implementing low carbon fuel standards in Oregon. This analysis is available on DEQ's website at: http://www.deq.state.or.us/aq/committees/lowcarbon.htm.

Electric vehicles and plug-in hybrids

Generally, utilizing electric or hybrid vehicles results in a GHG emissions reduction range of 0.4 to 20.3 percent (CAPCOA 2010). Vehicle miles fueled by electricity emit less CO_2 than vehicles fueled by gasoline, and when charged overnight using off-peak renewable resources, emissions are further reduced. As the share of renewable resources increases, the emissions profile of the power sector will continue to improve to further reduce the CO_2 emissions.

One study found that even if plug-in hybrids are powered by the current grid, and even if all the energy came from an old coal power plant, carbon emissions are less compared to a petroleum-fueled vehicle. A conventional gasoline vehicle produces 450 grams of CO_2 per mile, while a plug-in hybrid charged with power from an old coal plant would be responsible for 325 grams of CO_2 per mile, which equates to a reduction of 25 percent. This scenario still leaves room for further CO_2 reduction if the vehicle is powered by more renewable resources (EPRI and NRDC 2007).

All in all, cumulative nationwide GHG savings from 2010 to 2050 can range from 3.4 to 10.3 billion metric tons of CO_2-equivalent depending on the penetration level of plug-in hybrid vehicles and amount of energy emissions. Under a "best case" scenario with a high percentage (85 percent) of plug-in hybrids and low CO_2 from the electric sector, annual GHG savings amounted to 612 million metric tons annually. Even under a scenario with a medium percentage (41 percent) of plug-in hybrids, fuel savings equated to 2 million barrels daily in 2030 and 3.7 million barrels daily by 2050 (EPRI and NRDC 2007).

When considering the Neighborhood Electric Vehicle alone, the mode shift from traditional vehicles to microtransit results in a 0.5 to 12.7 percent VMT reduction (CAPCOA 2010).

Case Study: Electric Vehicle and Charging Infrastructure Test Markets

Overnight charging at home will decrease some of the need for public charging, but accessible public facilities are important in increasing consumer confidence (Electrification Coalition 2009). The US Department of Energy distributed federal stimulus funds to ECOtality to test the deployment of electric vehicles and charging infrastructure in Oregon and six other test markets. A partnership with Nissan will deploy approximately 1,000 Nissan electric cars in Oregon and install approximately 2,500 charging stations at homes and businesses. The EV project will collect vehicle and charge information in return for providing household or public charging stations (ODOT: OIPP).

Nationwide, the ECOtality program is projected to result in the reduction of CO_2-equivalent emissions by 2.3 billion pounds in five years and 27.1 billion pounds in ten years (ECOtality).

Caveats on research

The effect of vehicle technology is complex. The GHG emissions reduction potential varies depending on the energy mix used to generate the electricity to recharge the vehicles (Elgowainy, et al 2010). Vehicle technology and fuel strategies have been shown to be effective when paired with one set of strategies, but less effective when paired with others. For example, although fuel economy improvements reduce GHG emissions per VMT, higher fuel economy can raise vehicle prices, which could reduce fleet turnover and potentially cause less fuel-efficient vehicles to remain on the road longer. Another consideration is the rebound effect, whereby improved fuel economy could encourage additional VMT. It is important to consider which of the various strategies outlined in the Toolbox will be most effective at reducing GHG emissions.

Co-benefits and synergy with other strategies

Co-benefits

Beyond reducing VMT and GHG emissions, changes to vehicle technology and fuels have the potential to provide other important co-benefits to a community. Co-benefits include:

Public health benefits:

- Improved air quality and fewer air toxics emissions, leading to reduced risk of asthma, lung disease and premature death

Environmental benefits:

- Lower levels of pollution
- Less energy use

Economic benefits:

- Job opportunities
- Leverage private investments
- Consumer savings
- Reduced fuel consumption; reduced reliance on foreign oil
- Increased energy security

Synergies with other strategies

Synergy exists when a combination of two or more strategies enhances the potential GHG emissions reduction from an individual strategy. Changes to vehicle technology and fuels are synergistic with several other strategies including:

- Mixed-use development in centers and corridors
- Public education and marketing
- Individualized marketing
- Fleet mix and turnover

Considerations moving forward

Research and development is vital to improving fuel and advancing vehicle technology. A combination of vehicle technology and fuels strategies should be considered, as opposed to one strategy alone, in order to be effective at reducing GHG emissions.

The vast majority of Oregon's transportation fuels are produced out-of-state; approximately $5 billion left Oregon's economy in 2008 to import transportation fuels. Jack Faucett Associates' (JFA's) analysis shows that with low carbon fuel standards, Oregon's employment, average personal income and gross state product all grow, when compared to the economy without the standards. To meet the low carbon fuel standards, significant investment in lower carbon fuels production capacity and fuel distribution infrastructure will be needed (DEQ 2011). Regardless of where low carbon fuel is produced, infrastructure to deliver that fuel will be needed in

Oregon. In particular, installing electric vehicle charging equipment or natural gas dispensing equipment in earlier years would produce economic benefits sooner because its existing distribution system makes it easier and cheaper to implement. JFA's analysis also shows that the low carbon fuel standards would result in lower costs at the pump for fuel users, leaving more funds available for other things

In addition, the electric vehicle market is likely to encompass a diverse set of vehicles including, in addition to more standard electric cars, low-speed neighborhood electric vehicles, medium speed electric vehicles, one- or two-seater electric vehicles that are classified as motorcycles (e.g. Archimoto, Aptera), electric bicycles, and electric scooters. This will present new challenges for planning future street networks because not all of these vehicles mix equally well with cars, light trucks and heavy trucks and buses. For example, slow and medium speed neighborhood electric vehicles are limited to certain road speed classes.

The market for electric vehicles depends on the availability of charging opportunities at home, work-sites and other public destinations. The provision of charging stations is subject to local control. If charging locations are provided, then the potential market of EVs will be increased. If that does not occur, then the potential market will be decreased (all else equal). It will be important for regional and local plans and policies to address these issues, complementing other efforts underway at the Federal and State levels.

Recommendations for supporting electric vehicles are highlighted in the *Transportation and Land Use Roadmap to 2020* report to the Oregon Global Warming Commission (OGWC). The primary recommendation is to deploy an Oregon Electric Vehicle Strategy to double the projected 2020 national level (about five percent of total fleet) of light duty vehicles registered as electric or plug-in hybrid. Additional recommendations are derived from the *Electrification Roadmap* report by the Electrification Coalition.

Recommendations for batteries and vehicles (OGWC):

- Encourage electric vehicle purchases through incentives such as tax credits and other incentives
- Offer incentives for electric vehicle fleet purchases and setting purchase standards for government fleets
- Redesign urban streets to accommodate two- and three-wheeled, low-speed vehicles

Recommendations for charging infrastructure (Electrification Coalition 2009):

- Encourage charging stations and infrastructure through tax credits and other incentives
- Deploy smart grid technology for charging stations to reduce the need for utility infrastructure upgrades
- Modify building codes to allow for charging stations in homes

At the state level, new projects and existing projects should be supported with the necessary research and development funding. Since the biggest limitation for drivers considering the purchase of an electric vehicle is the absence of a reliable network of charging facilities, a careful approach should be considered as this infrastructure is built (ODOT: OIPP). Utilities should be granted assurance that their investment in charging infrastructure will be supported, and that utilities will be allowed to change their rate structure to accommodate electric vehicles and plug-in hybrids into their utility load curves (Electrification Coalition 2009). Existing electric vehicle -related projects (also see case study insets) in Oregon include the EV Project by ECOtality, the West Coast Green Highway initiative, the Oregon EV roadmap, and the Tiger II Grant for EV infrastructure (ODOT: OIPP).

At the federal level, regulations should be standardized for electric vehicles and the related infrastructure. Policies should promote the harmonization of technical standards, environmental valuation, and safety requirements. Efforts can also be coordinated with the private sector to develop and demonstrate electric vehicle technologies. Additionally, consumer education and formal training for future engineers is necessary in order to encourage the deployment of electric vehicle technologies (EDTA 2011). National projects include Charge Point America, the National Plug-In Vehicle Initiative, Plug In America, and Project Get Ready.

Who implements

Technology and fuel strategies, like fleet mix and turnover strategies, are best implemented at the state and federal levels because of the unknowns of potential types of vehicle technologies, how quickly such changes occur over time, and the type and timing of policies and laws adopted at the federal and state levels. Since technology improvements require funding for research, partnerships with businesses and educational institutions with related interests can provide an important platform from which to move forward.

In addition, vehicle purchases provide an important opportunity for governments and private sector companies to adopt a leadership role in the deployment of alternative fuel vehicles. The selection of right-sized vehicles when replacing fleet vehicles can reduce vehicle and fuel costs for the fleet. State fleets can help emergent technologies to receive greater exposure to consumers, and ultimately facilitate the transition towards lower emission levels of the transportation sector.

At the local level, policy changes can be made to encourage acceptance of low-carbon fuels and electric vehicle and plug-in hybrid technology. Policy changes that can be considered at the local level include: the installation of a streamlined permitting process for electric vehicle charging stations in homes and publicly, commitment to electric vehicle turnover for local fleets; and offering registration fees, sales taxes or preferential parking for electric vehicles or plug-in hybrids (Electrification Coalition 2009).[5]

[5] The Puget Sound Regional Council has produced a model guidance document for local governments working to meet Washington's new electric vehicle infrastructure law, which may serve as a resource in the coming phases. See: http://psrc.org/transportation/ev/model-guidance

IV. CONCLUSION

The Portland metropolitan region has choices about how to respond to the climate challenge. Through the Scenarios Project, the region will build on a long tradition of innovation, excellence in planning, and conservation and stewardship of the natural environment. The bold decisions made decades ago have given the region a head start over other places across the country. It is in this context that the region will consider the bold actions needed to tackle the climate challenge and show that solutions are at hand to turn this challenge into an opportunity to enhance our region's resilience, prosperity and quality of life, now and for generations to come.

Overview of Phase 1 Research and Analysis – Understanding Choices

Phase 1 of the Climate Smart Communities Scenarios project is focused on understanding the region's choices by testing broad-level, regional scenarios to learn the GHG emissions reduction potential of current plans and policies and what combinations of land use and transportation strategies (grouped in six policy levers) are needed to meet the state GHG targets. While some strategies are new to the region, many of the strategies tested are already being implemented to realize the 2040 Growth Concept and the aspirations of communities across the region.

In June 2011, the region discussed and agreed to six guiding principles to undertake this effort:

- **Focus on outcomes and co-benefits:** The strategies that are needed to reduce GHG emissions can help save money for individuals, local governments and the private sector, grow local businesses, create jobs and build healthy, livable communities. The multiple benefits should be central to the evaluation and communication of the results.
- **Build on existing efforts and aspirations:** Start with local plans and 2010 regional actions that include strategies to realize the region's six desired outcomes.
- **Show cause and effect:** Provide sufficient clarity to discern cause and effect relationships between strategies tested and realization of regional outcomes.
- **Be bold, yet plausible and well-grounded**: Explore a range of futures that may be difficult to achieve but are possible in terms of market feasibility, public acceptance and local aspirations.
- **Be fact-based and make relevant, understandable and tangible:** Develop and organize information so decision-makers and stakeholders can understand the choices, consequences (intended and unintended) and tradeoffs. Use case studies, visualization and illustration tools to communicate results and make the choices real.
- **Meet state climate goals:** Demonstrate what is required to meet state the GHG emission reduction target for cars, small trucks and SUVs, recognizing reductions from other emissions sources must also be addressed in a comprehensive manner.

Tables 8 -10 summarize the co-benefits of the strategies described in the Toolbox and synergistic relationships among strategies. Based on the literature review in the previous chapter, as well as input from regional decision-makers, Metro worked with a technical work group to design and test combinations of strategies for their effectiveness in reducing GHG emissions from light duty vehicles – as required by House Bill 2001 - to explore a range of possible approaches to meet the state climate goals. The results of that work will be reported in a separate report.

Next steps

This document will serve as important background information for the Scenarios Project, and be used in conjunction with the scenarios analysis to inform development of findings and recommendations for discussion by the region's decision-makers. The results of the Phase 1 analysis will be summarized and brought forward for discussion by the region's decision-makers in fall 2011.

The first phase of the Scenarios Project is not about 'picking a winner' from the set of scenarios evaluated, but exploring a range of possible approaches to inform a regional discussion on the associated opportunities, challenges and implications for the region and state. The regional policy discussion will shape the findings forwarded to Phase 2 of the Scenarios Project. Phase 2 is where the region will begin to integrate individual community aspirations into the planning process and identify the policies and strategies to emphasize and where they could be applied. While solutions might vary from one community to another, each community will have an important role to play in helping the region meet the state climate goals.

While reducing GHG emissions is important to the health of the region and the planet, it is the intent of the Scenarios Project to also demonstrate that the region can meet the state climate goals and achieve outcomes of equal importance to residents: a healthy economy; clean air and water; and access to good jobs, affordable housing, transportation options, nature, trails and recreation. For now, this effort will focus on mitigation of GHG emissions from cars, small trucks and sport utility vehicles; preparation for and adaptation to a changing climate will be addressed through other efforts already underway at the community, regional and state levels.

Selecting strategies for implementation in Phase 3 will involve policy decisions that could have political, economic, equity, community, and lifestyle implications. By identifying the policy choices and tradeoffs that decision-makers will need to consider throughout the process, this research can serve as a basis for continuing a regional dialogue on how to confront the threat of global climate change through state, regional and local actions while advancing the region's efforts to build livable, prosperous and equitable communities.

Table 8. ECONOMIC CO-BENEFITS COMPARISON

		COMMUNITY DESIGN			PRICING		MARKETING AND INCENTIVES			MANAGEMENT		TECHNOLOGY AND FUELS	
		Mixed-Use Development in Centers and Corridors	Active Transportation and Complete Streets	Public Transit Service	Parking Pricing	Tolls, Fees and Insurance	Public Education and Marketing	Individualized Marketing	Employer-Based Commuter Programs	Traffic Management	Traffic Incident Management	Fleet Mix and Turnover	Vehicle Technology and Fuels
Economic Benefits	Job opportunities	●	●	●			●	●	●			●	●
	Increased access to jobs, goods and services	●	●	●		●	●	●	●	●	●		
	Leverage private investments; increased local tax revenues	●	●	●									●
	New revenues	●			●	●							
	Reduced fuel consumption; reduced reliance on foreign oil			●	●		●	●	●	●	●	●	●
	Consumer savings	●	●	●			●	●		●	●	●	●
	Municipal savings	●	●										
	Increased energy security	●											●
	Increased cost effectiveness of transit investments	●	●	●	●		●	●	●				

Table 9. PUBLIC HEALTH AND ENVIRONMENTAL CO-BENEFITS COMPARISON

		COMMUNITY DESIGN			PRICING		MARKETING AND INCENTIVES			MANAGEMENT		TECHNOLOGY AND FUELS	
		Mixed-Use Development in Centers and Corridors	Active Transportation and Complete Streets	Public Transit Service	Parking Pricing	Tolls, Fees and Insurance	Public Education and Marketing	Individualized Marketing	Employer-Based Commuter Programs	Traffic Management	Traffic Incident Management	Fleet Mix and Turnover	Vehicle Technology and Fuels
Public Health & Safety Benefits	Increased physical activity, leading to reduced risk of	●	●	●	●	●	●	●	●				
	Enhanced public safety; reduced traffic injuries and fatalities	●	●	●		●	●	●		●	●		
	Improved air quality and fewer air toxics emissions, leading to reduced risk of asthma, lung disease and premature death	●	●	●	●	●	●	●	●	●	●	●	●
Environmental Benefits	Lower levels of pollution	●	●	●	●	●	●	●	●	●	●	●	●
	Less energy use	●	●	●		●	●	●	●	●	●	●	●
	Natural areas, farm and forest protection	●											

Table 10. SYNERGY WITH OTHER STRATEGIES

	COMMUNITY DESIGN			PRICING		MARKETING AND INCENTIVES			MANAGEMENT		TECHNOLOGY AND FUELS	
	Mixed-Use Development in Centers and Corridors	Active Transportation and Complete Streets	Public Transit Service	Parking Pricing	Tolls, Fees and Insurance	Public Education and Marketing	Individualized Marketing	Employer-Based Commuter Programs	Traffic Management	Traffic Incident Management	Fleet Mix and Turnover	Vehicle Technology and Fuels
Mixed-Use Development in Centers and Corridors		●	●	●		●	●	●	●		●	
Active Transportation and Complete Streets	●		●	●		●	●	●				
Public Transit Service	●	●		●	●	●	●	●	●		●	
Parking Pricing	●	●	●					●	●			
Tolls, Fees and Insurance			●			●		●	●			
Public Education and Marketing	●	●	●		●		●	●	●		●	●
Individualized Marketing	●	●	●			●						●
Employer-Based Commuter Programs	●	●	●	●	●	●						
Traffic Management	●		●	●	●	●				●		
Traffic Incident Management									●			
Fleet Mix and Turnover	●		●			●						●
Vehicle Technology and Fuels	●					●	●				●	

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