Transportation Greenhouse Emissions Analysis and Report

City of Bloomington

Prepared by:

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Background and Purpose

The City of Bloomington is working to reduce carbon emissions sector-wide to advance its target of achieving carbon neutrality by 2050. As part of this effort, the City is working to better understand carbon emissions from its surface transportation system and use this knowledge as a base for future policy and infrastructure development.

Figure 1: Bike ride at school (City of Bloomington)

The study developed methods to estimate and calculate vehicle miles traveled (VMT) and associated carbon emissions. Using these estimates, scenarios to achieve the City's goal of carbon neutrality by reducing VMT and electrifying transportation were developed. An analysis was conducted of travel behavior in the city to better understand trip purpose and lengths. The remainder of the study focused on identifying ways to reduce driving—a key component of transportation emissions reduction. As other City plans have focused on vehicle electrification, it was not a focus of this study.

Following these analyses, a set of strategies and associated action items to move the City towards a carbon neutral transportation system were developed.

The study was carried out between September 2023 and May 2024.

Existing Conditions Analysis

As a first step, an existing conditions analysis of transportation infrastructure and funding in Bloomington was carried out.

Current Plans, Policies and Programs

To ensure that the study's analysis framework and recommendations were created in context with other City policies, programs and priorities, the following were reviewed:

- Bloomington's Strategic Plan (Bloomington. Tomorrow. Together.)
- Bloomington's Comprehensive Plan (Forward 2040)
- Capital Improvement Plan
- Energy Action Plan
- Reports from the Office of Racial Equity, Inclusion and Belonging
- Bloomington's Active Transportation Action Plan
- Bloomington Electric Vehicle Infrastructure Plan
- City zoning code

This analysis revealed the following opportunities to advance other City priorities:

- Aligning the study with Bloomington's net-zero carbon goal.
- Furthering the sustainability work being carried out by City staff and the City's Sustainability Commission.
- Advancing equity and inclusion within transportation.
- Advancing public health.
- Increasing the quality and number of community amenities.
- Advancing economic inclusion and development.

Carbon Emissions in Bloomington

Data from the Regional Indicators Initiative, CenterPoint Energy and Xcel Energy were used to create a profile of carbon emissions trends in Bloomington between 2015 and 2022.

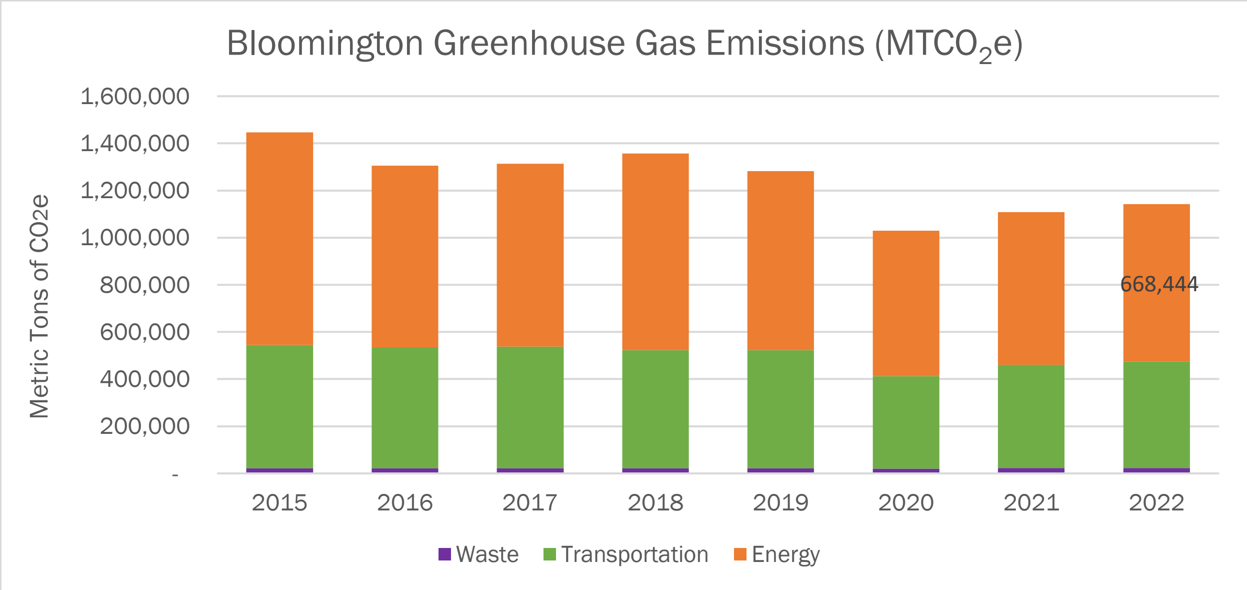

Figure 2: Greenhouse gas emissions in Bloomington (Source: City of Bloomington, Metropolitan Council and Xcel Energy)

The analysis revealed that approximately forty percent of all carbon emissions within the City come from the transportation sector, the second largest source of emissions behind electricity and natural gas use. Transportation emissions have remained relatively steady over the past decade, while some progress has been made in reducing emissions from energy generation. In 2022, transportation was responsible for 451,907 metric tons of carbon emissions. Transportation makes up a much larger proportion of total emissions in Bloomington, compared to the entire Twin Cities Metro area—where approximately 22 percent of emissions are from the sector[1].

Carbon Emissions from Transportation in Bloomington

Within the transportation sector, emissions from driving cars and small trucks are responsible for approximately 93 percent of all carbon emissions. The remainder comes from large trucks and transit vehicles[2].

Transportation Affordability and Car Ownership

An analysis was conducted using Center for Neighborhood Technology's Housing + Transportation Affordability index tool. The goal of the analysis was to gain a better understanding of housing and transportation costs in Bloomington, and compare the results to Hennepin County as a whole.

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[1] Greenhouse Gas Emissions Inventory. 2024. Metropolitan Council. https://metrocouncil.org/Data-and-Maps/Research-and-Data/Climate-tools.aspx

[2] Regional Indicators Initiative. 2022. LHB. https://www.regionalindicatorsmn.com/city-summary

Bloomington | Hennepin County

Figure 3: Transportation costs, autos per household and household VMT in Bloomington and Hennepin County

The analysis found that Bloomington on average spent more on transportation costs, drove more miles and owned more automobiles per household compared to the county as a whole.

Review of Bloomington's Capital Investment Plan

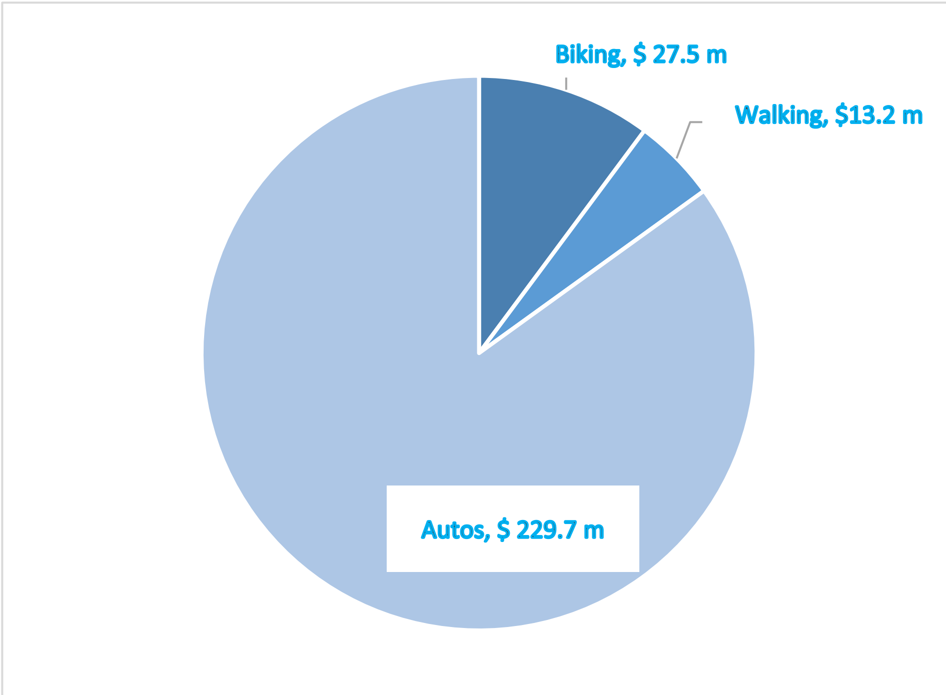


Figure 4: Bloomington Transportation Capital Improvement Plan(2024-2033)

A review of Bloomington's latest Capital Improvement Plan (CIP) was conducted. This is a planning document that uses long range physical and financial projections that forecast capital investment needs over ten year periods. The CIP includes a detailed description of every capital project anticipated between 2024 and 2033. The review provided a snapshot of Bloomington's transportation investment plans divided between automobile, active transportation and pedestrian infrastructure. The graphic below shows the results of the analysis. It is to be noted that there are several roadway projects that have an active transportation or pedestrian infrastructure component that are not reflected in the CIP as it stands.

Infrastructure Inventory

The study team carried out an inventory of existing transportation infrastructure that currently exists in the City of Bloomington. The following tables show existing transportation infrastructure by mode and mileage.

Table 1: Inventory of existing transportation infrastructure (Source: City of Bloomington, Metropolitan Council)

Facility Type	Existing Mileage
Vehicle lane miles	1,029
Sidewalks	241
Multi-use trails	84
Level 3 EV chargers	16
Level 2 EV chargers	74
Active transit stops	501
Inactive transit stops	627
Transit stops with shelters or benches	37

Travel Behavior Analysis

An analysis was carried out to understand better how and why people travel in Bloomington. This analysis included all trips that had an origin or destination within city limits. The following graphics showcase the results of this analysis. A detailed overview of the analysis methodology is provided in Appendix A. A key goal of this analysis was to understand how trip-making relates to an increase in vehicle miles traveled (VMT)— i.e. how individual types of trips combine to result in overall driving behavior. The following charts show the results of trip making behavior and their contribution to VMT.

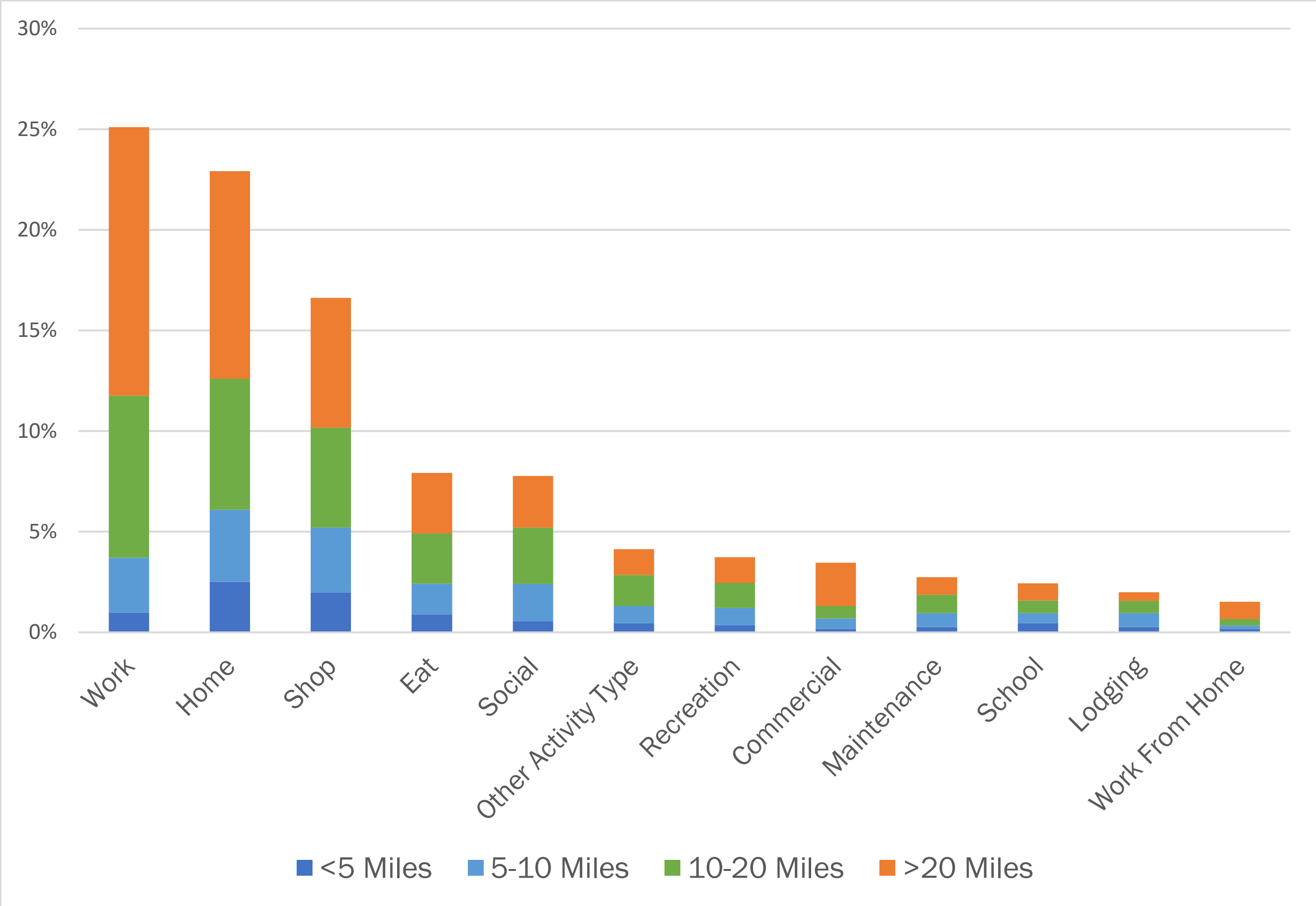


Figure 5: Trip purpose by distance and contribution to VMT

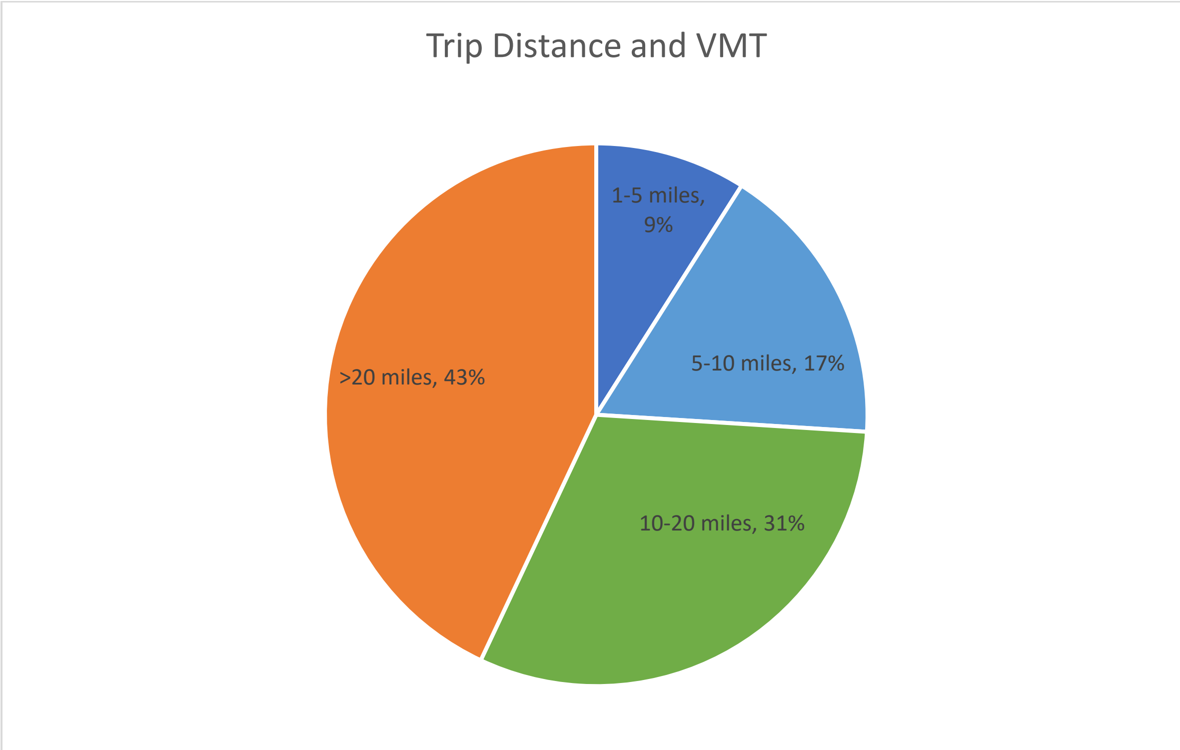


Figure 6: Trip distance by contribution to total VMT

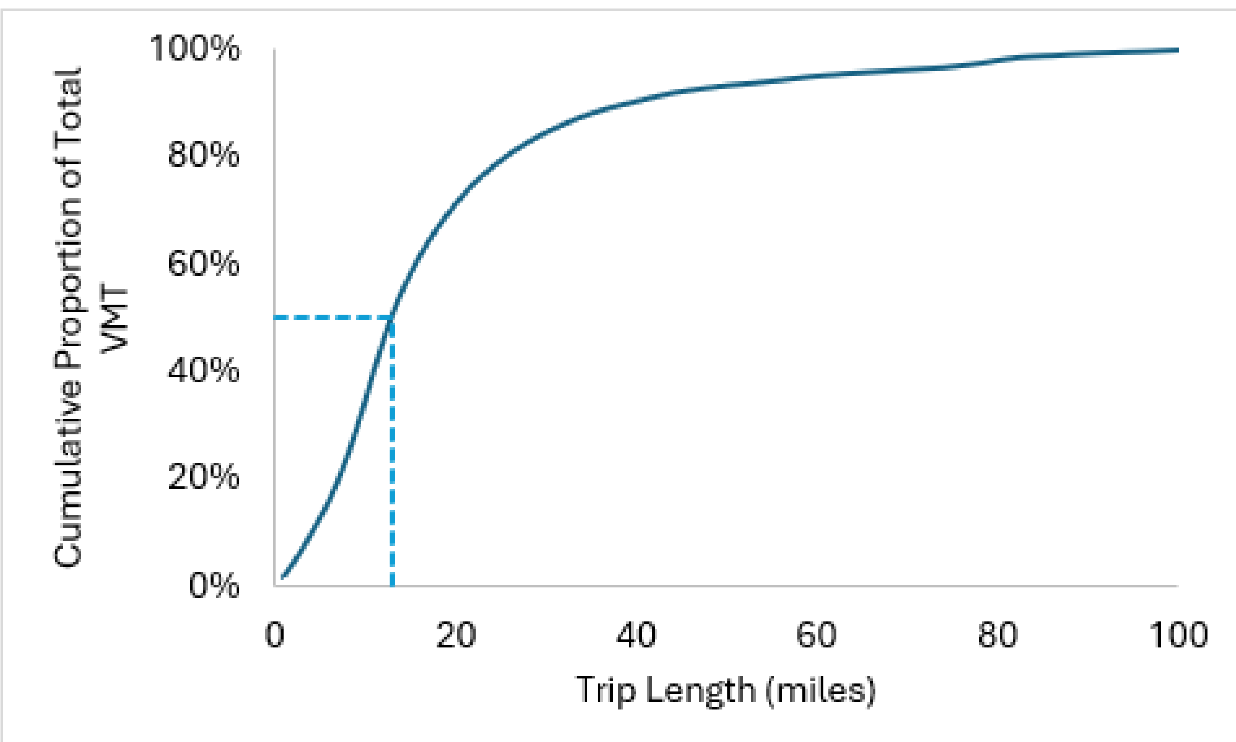


Figure 7: Cumulative VMT as a result of trip length

Existing Conditions: Key Takeaways

The existing conditions analysis revealed that reducing or eliminating transportation emissions will be critical to achieving the City's net zero goal by 2050. Within transportation it will be necessary to focus on tackling emissions produced by driving cars and small trucks as they make up the majority of carbon pollution in the City. Currently, the City spends the largest share of the capital improvement budget on car-centric infrastructure. Bloomington residents spend more on transportation costs and drive more compared to Hennepin County as a whole. In addition, Bloomington households own more cars than the County as a whole. The analysis also revealed that the majority of the public right of way is dedicated to the storage and movement of cars and small trucks. Opportunities therefore exist for significant investment in expanding sidewalks, biking, rolling, and transit infrastructure.

The travel behavior analysis showed that currently 9% of VMT comes from trips that are between 1 and 5 miles length. The average adult can walk one mile or bike three miles in about 15-20 minutes. Trips of this distance could potentially **shift** to walking or biking trips. While people have many reasons for driving distances under 3 miles, a coordinated approach that considers infrastructure, community planning, education and encouragement strategies could help encourage more of these trips to be made on foot, bicycle or – where service is available – transit.

Currently, 17% of VMT comes from trips between 5-10 miles in length. Within these trips, there are opportunities to **shorten** trips over time through coordinated planning efforts. There are also opportunities to **shift** some of these trips to e-bike, transit, virtual or carpool.

Trips greater than 10 miles in length make up 74 percent of VMT. These trips are harder to be shifted to walking and biking modes. A combination of strategies may be useful to address driving reduction on these trips including using multiple modes, such as transit for a large part of the trip with a biking trip used for making the last mile connection. Many of these trips may also be decarbonized through electrification.

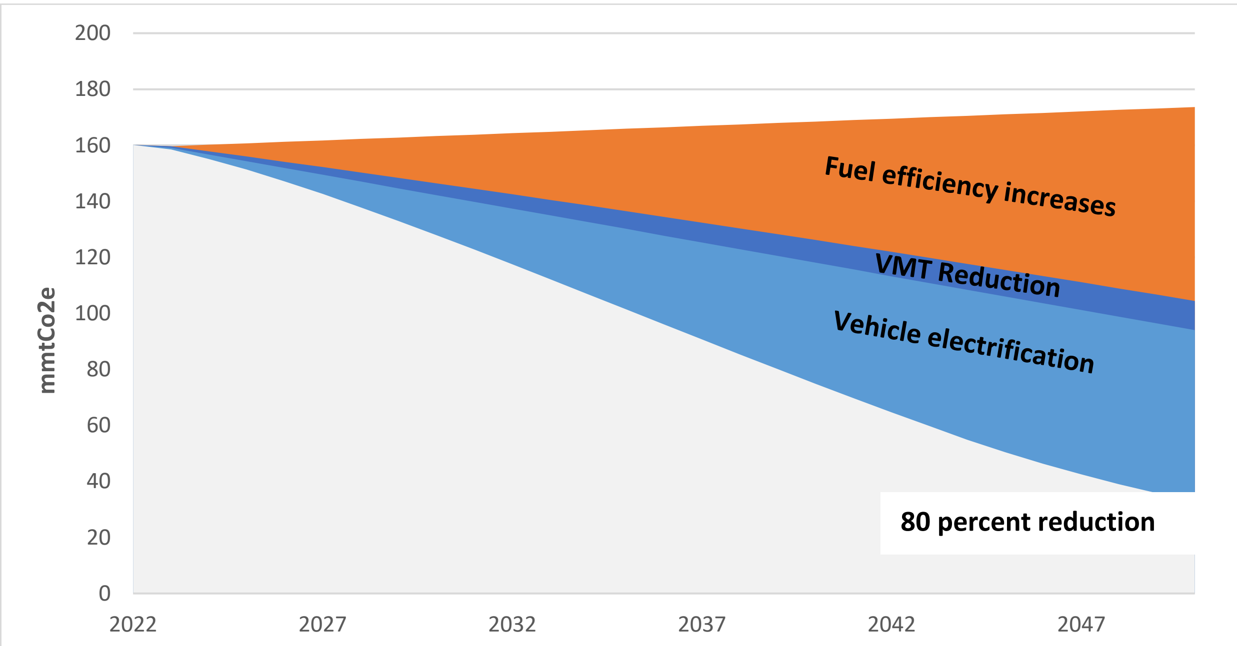
The analysis of current travel behavior also looked at trip purpose to understand how traveling to different types of destinations contributes to the number of car and taxi trips in Minnesota and the amount of VMT from each of those trip types. The trip types included were: home, work, shop, social, eat, errands, recreation, school, and other. Trips to work made up the largest share of trips, at 25% of all trips. Work trips are the longest type of trips on average across Bloomington, with a majority of trips being greater than 20 miles in length. Trips back home were about 23% of all trips, reflecting that people travel back to their home from many types of destinations.

Greenhouse Gas Reduction Scenarios

Achieving Bloomington's transportation greenhouse gas emissions reductions goals will require reductions sector-wide. To help understand the different pathways through which the City could achieve these goals based on different policy and infrastructure investment inputs, the study team developed four scenario-alternatives. Scenarios were developed to understand the extent to which driving needs to be reduced citywide, in addition to the extent to which the vehicles need to be electrified to drive down emissions. A comprehensive overview of the methods used to develop these scenarios are presented in Appendix A.

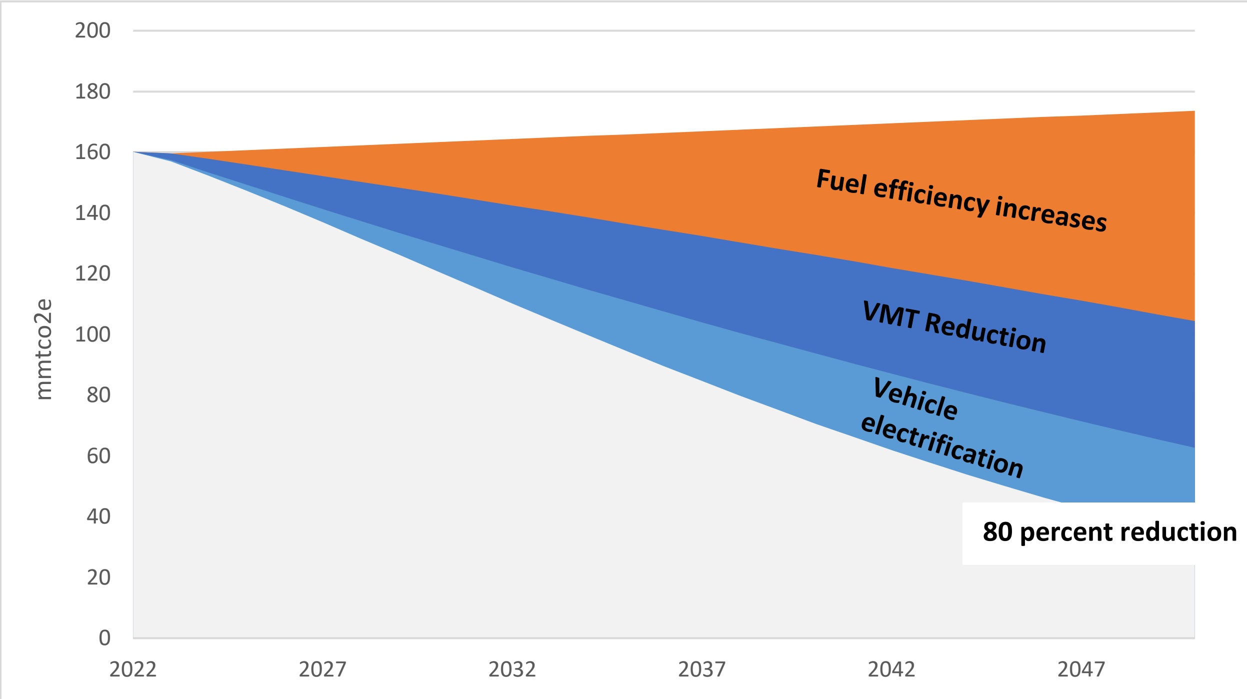
Each of the colored wedges shown in the graphics below show a reduction in carbon from 2024, adding up to meet an absolute carbon reduction estimate of 80 percent from today's levels by 2050. The orange wedge shows predicted increases in automotive fuel efficiency that will read to emissions reductions without additional action by the City. Layered below those are emissions reductions from lowered VMT shown in dark blue. The final wedge shows the extent of electrification of vehicles required citywide in orange.

Scenario 1: High Electrification



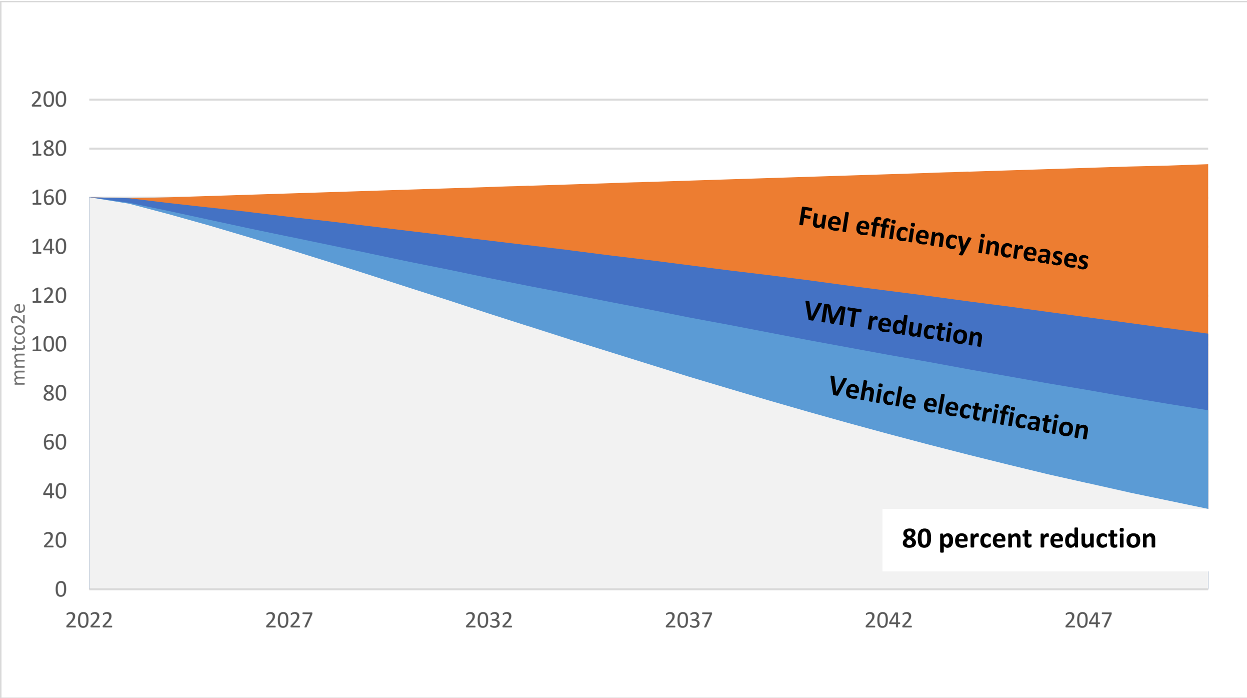
This scenario focused on a pathway to decarbonization based on a high rate of vehicle electrification. This scenario showed that a higher focus on electrification will require 65 percent of all vehicles to be electrified and all new vehicle sales to be EVs by 2045. The remaining emissions would come from reducing VMT by 10 percent by 2050.

Scenario 2: High VMT Reduction



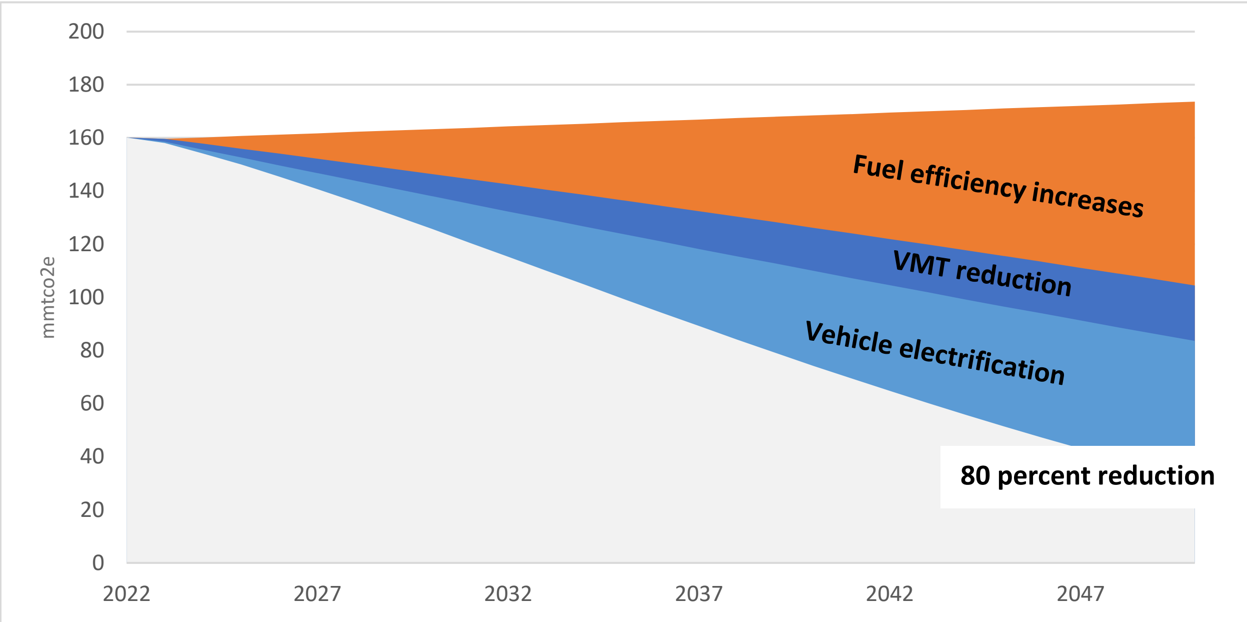
This scenario focused on a pathway to decarbonization based on reducing driving by 45 percent from current levels by 2050. This scenario showed that to achieve that goal, 45 percent of all cars on the road need to be electrified and all new vehicles sold must be electric by 2050.

Scenario 3: Middle of the road 1



This scenario aimed to strike a balance between driving reduction and vehicle electrification, with a slightly higher focus on reduced driving. In this scenario, a pathway was established to reduce driving by 30 percent from current levels by 2050. This requires electrifying 55 percent of all on-road vehicles and all new vehicles sold to be electric by 2050.

Scenario 4: Middle of the Road 2



This scenario aimed to strike a balance between driving reduction and vehicle electrification, with a slightly higher focus on increased electrification. In this scenario, a pathway was established to reduce driving by 20 percent from current levels by 2050. This requires electrifying 60 percent of all on-road vehicles and all new vehicles sold to be electric by 2050.

VMT Reduction Framework

The study has identified a framework to achieve the City's VMT reduction goals that has three components: 1) **shifting** driving trips to other transportation options, 2) avoiding trips by making to possible to meet your needs without traveling in your own vehicle, 3) **shortening** driving trips so that fewer vehicle miles are traveled, and 4) **incentivizing** the use of other modes besides personal vehicles.

The first component of the VMT reduction framework is **shifting** trips from driving to other transportation mode choices. This could mean shifting current driving trips to virtual, transit, walking, biking or carpool trips. Some ways to achieve a shift away from driving trips include investing in transit routes with improved travel speed and reliability (with features such as dedicated transit lanes, high frequency service and improved ticketing and boarding), building out sidewalks and keeping them clear of snow and ice in winter and free from excessive heat in summer, and creating networks of separated bike paths that provide comfort and safety to riders of all ages and abilities.

The second component of the VMT reduction framework is **shortening** driving trips. Reducing the distance that people must travel to reach their destinations will reduce VMT. This can be achieved by building our communities in a way that increase the number of destinations that are closer together. For example, if a neighborhood includes a grocery store and pharmacy within walking distance of homes, people will not have to drive long distances to access these services. If more people are able to live in communities that are compact with destinations close together, connected by transit, walking and bicycling networks that serves people of all ages and abilities, there is more opportunity for people to take shorter trips throughout the city.

The third component of the framework is **avoiding** trips. With advances in technology brought about by high-speed internet and better video communication tools, it may be possible to access work and services without making a physical trip. This allows for more needs to be met from the comfort of one's home, while saving money and time on transportation.

Finally, another way to achieve VMT reduction is by **incentivizing** the use of modes of transportation that don't require one to drive. For example, workplaces could provide free bus passes to encourage employees to use public transportation. The corollary of this is to disincentivize driving alone through strategies such as pricing on parking, driving on certain corridors, fuel, or VMT.

How does Bloomington Influence Travel Behavior?

To identify strategies that reduce driving, the study looked at the ways that the City might influence current and future travel behavior decisions. The way that people travel is influenced by multiple factors, including the cost of transportation options, the time it takes to travel by a particular mode, distance to destinations, the convenience and reliability of transportation options and physical ability. While some of these transportation choices are based on personal preference, transportation behavior is influenced by the built environment, including the design and operation of roads. For example, if a driving trip takes 30 minutes and a transit trip to the same destinations takes 2 hours, most people who have the economic and physical ability to drive will choose the driving trip. Similarly, if a destination is close enough to walk or bicycle, but there is not safe and comfortable walking and biking infrastructure, many people who have a choice will choose to drive.

The study found four major areas within which the City could advance driving reduction goals. These include:

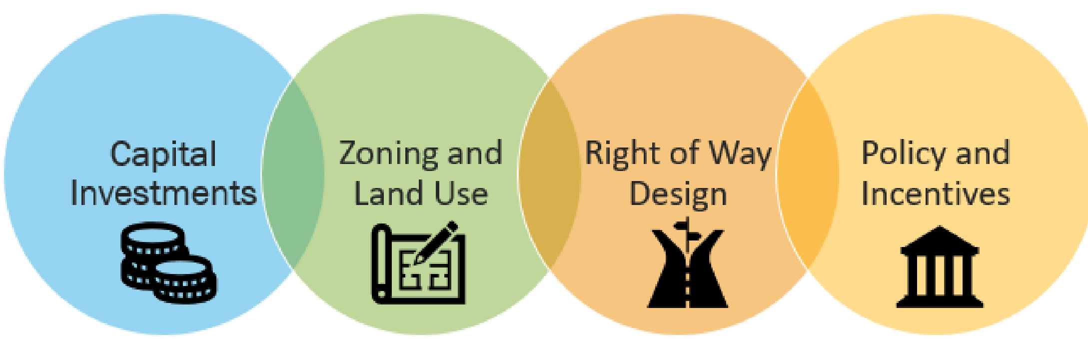


Figure 8: City travel behavior influence areas

Capital Investments: The City will spend approximately $270 million over the next decade on new capital investments. These investments will impact travel behavior by shaping the type of transportation projects that will be prioritized.

Zoning and Planning: Land use is a critical piece of influencing travel behavior. Land use planning and zoning that encourages closer destinations and denser, walkable neighborhoods has been shown to reduce VMT and encourage the use of active transportation, biking and public transit.

Right of Way Design: The look, shape and feel of city roads and streets play a significant role in how people use them. Streets that are primarily designed for automobility encourage more driving, while those that prioritize the needs of multiple modes may encourage the use of walking, biking and transit. The City has primary responsibility for the planning, design and maintenance of the majority of streets within its limits, while others are overseen by Hennepin County and Minnesota Department of Transportation.

Policy and Incentives: The City through its elected officials and commissions sets standards, policies and practices that influence travel behavior among other things. Using policy tools at its disposal, the City can encourage travel behavior that results in lower carbon emissions from the transportation sector.

Strategies and Actions

Based on the framework and areas of City influence identified above, a series of example strategies and actions were identified as potential steps that could be taken to achieve carbon emissions from transportation by reducing VMT. Strategies are higher level guidelines, within which specific action steps may be situated. The strategies were developed using the following guiding principles based on our review of existing Bloomington plans, policies and efforts:

Guiding themes:

- Increase safe and reliable access to city destinations without the use of a private vehicle.
- Mitigate historical harms and bring equity to marginalized communities.
- Reduce transportation cost burden for low-income communities.
- Consider housing and transportation decisions together.
- Improve public health through effective transportation and land use decisions.
- Eliminate deaths and injuries from traffic crashes.

Strategies:

The following high-level strategies were identified as examples for further exploration by the City.

Shifting Modes

- Right-size transportation infrastructure.
- Increase frequency, connectivity to destinations, and reliability of public transit.
- Increase transit access and connectivity.
- Increase safety, comfort, and convenience of active transportation.
- Decrease economic barriers to walking, biking, rolling and transit modes.

Figure 9: Passengers in a metro transit light rail car (City of Bloomington)

Avoiding Trips

- Encourage transportation demand management strategies.
- Encourage shared mobility like carpooling.
- Increase virtual access to basic needs (telework, telehealth, etc.)

Figure 10: Different types of travel demand management strategies

Shortening Trips

- Encourage compact development and discourage sprawl.
- Support transit-oriented development.
- Increase availability of services that meet basic needs (childcare, grocery stores, healthcare, retail)
- Increase availability of specialty services

Figure 11: A new transit stop with amentiies located in Transit Oriented Development at 98th Street in Bloomington (City of Bloomington)

Incentivizing Trips

- Increase parking pricing (incrementally with proximity to urban centers) and/or reduce parking availability.
- Provide transit passes instead of free parking.
- Provide convenient parking and storage for bicycles.
- Subsidize e-bike purchases.

Figure 12: Full bike racks at Bloomington's City Plaza (City of Bloomington)

Example Actions

The following action steps were identified as examples for further exploration by the City.

Shifting Transportation Modes

1. Accelerate the build out of the city's bicycle network as identified in the Active Transportation Action Plan
2. Create a "pedestrian priority network" where improvements will be targeted.
3. Identify and create an inventory of sidewalk gaps that can be filled.
4. Identify local streets that may be downsized through 4-3 conversions.
5. Prioritize safe walking to transportation stops.
6. Invest in street crossing treatments that highlight pedestrian visibility and slow drivers.
7. Create clear policies for the safe operation of scooters and e-mobility on city streets.
8. Create driver education programs to improve the visibility and acceptance of those walking and biking on city streets.

Avoiding Trips:

1. Support comprehensive broadband access citywide to support telework and telehealth.
2. Provide technical or financial support for seniors and households with lower incomes to access telework and other essentials.
3. Work with local employers to support incentives for telework and carpool, transit, walking and biking to work.
4. Prioritize development that offers a mix of uses that allows for accessing essential services without having to drive.

Incentivizing Lower Carbon Trips:

1. Develop options to right-size citywide parking minimums along transit corridors.
2. Require developers and landlords to "unbundle" parking from rent.
3. Evaluate parking fees to fully capture the cost of parking in high demand areas.
4. Provide incentives for e-bikes purchases for low-income communities.
5. Work with partners to create local bike-share with regional connectivity.
6. Work with employers to create travel demand management plans that encourage mode shift such as "cashing out" parking benefits.
7. Provide transit signal priority on city-owned streets.

Shortening Trips:

1. Ensure shared mobility options are located within 0.25 miles of transit service to increase first and last mile options.
2. Require or provide complete streets infrastructure in areas with new development.
3. Over time, allow a mix of uses to support shifting to shorter trips through local land use and zoning changes.
4. Strengthen partnerships to encourage the siting of public buildings in areas that are accessible by transit, biking, and walking
5. Leverage transportation funding to support infill development

Example City Policies:

The study also explored example policies that the City could adopt to encourage reduced driving and lower transportation emissions:

1. Develop a Climate Action Plan that lays out a unified vision to achieve the City's transportation goals.
2. Consider setting a VMT reduction target citywide.
3. Consider adopting a Vision Zero Plan
4. Review the adopted Complete Streets Policy to assess for alignment with VMT and GHG goals
5. Encourage the use of metrics in addition to Level of Service (LOS) in determining transportation project success.
6. Consider adopting VMT reduction in project purpose and need.
7. Coordinate with City sustainability, public health, and the Office of Racial Equity, Inclusion, and Belonging and other divisions when setting transportation project goals.
8. Highlight walking, biking, and transit funding in City Capital Improvement Plan.

Appendix A: Data and Methods

Primary Data Used

There are three primary data types used throughout the analysis process: Vehicle Miles Traveled (VMT) data, vehicle emissions data, and vehicle cellular trace data (used through the Replica data platform).

VMT Data

VMT data was gathered from publicly available records published by the Minnesota Department of Transportation's (MnDOT) Linear Reference System and Roadway Characteristics Database. MnDOT publishes VMT data every year, across roadway functional classifications.

Of interest to this project was MnDOT's VMT data collected at the city level; MnDOT publishes the yearly VMT estimations for every city in the state. This VMT data is split by various roadway types (Interstate, US Highway, MN Highway, County State Aid Highway, Municipal State Aid Streets, and Municipal Streets).

This MnDOT data is measured and estimated from vehicle counts, where VMT can be calculated by multiplying the total vehicles counted for a segment of roadway with the length of that segment.

It is important to note about this data that it gets less accurate the lower the functional class and locality of the roadway. For many of the freeway types of roadways, VMT measures are more accurate as there is direct and continuous measures of vehicle counts. However, VMT counts on local roadways are estimated using extrapolation, making them less accurate.

Emissions Data

Emissions data was collected from the EPA Moves tool. This tool is used to estimate emissions impacts at a corridor level. While corridor level emissions were too fine-grained to be applicable to this project, the underlying emissions data used in the tool is still relevant. This data included emissions estimates for different vehicle types.

This is also paired with information on the vehicle split for roadways based on location in the country; this is done at the county level, so the vehicle split of Hennepin County was used.

This data also includes information on the differences in emissions per roadway classification, effectively giving emissions rates for highways and municipal streets. This data is reported as grams of GHG emitted per VMT per vehicle type. This also projects emissions into the future for all vehicle types and roadway classes.

Replica Cellular Trace Data

The study team used data from Replica, a proprietary travel analytics platform through existing SRF subscription. The applications provided by Replica run a seasonal, high fidelity simulation that represents the population and its travel patterns in Bloomington.

Replica cellular trace data was used to estimate the percentage of VMT in Bloomington that originated or ended within city limits. This data is also delineated between freeways and municipal streets. Trips that originated or ended outside city limits were excluded from this analysis.

Analysis Methods

Calculation of GHG Emissions per Roadway Type

The first step of the analysis was to estimate the total GHG emissions of each roadway type. Due to the various datasets, two roadway types were chosen for the remainder of analysis: municipal roads and highways. First, we must calculate the emissions profile for each roadway type. This was calculated by multiplying the 2022 emissions of each vehicle type by the percentage that vehicle type has on the roadway type, then summing all these emissions. This gives an average rate of GHG emissions per VMT, for each of the two roadway types.

This same process was used to calculate the future emissions in 2030 that will be used in the following analyses. Once GHG emissions per VMT is calculated, to calculate total GHG produced in 2022; multiply the emissions per VMT for each roadway type with the total VMT of each roadway type. This gives a total value of GHG emitted in 2022 by the transportation sector per roadway type, reported in tons of GHGs produced.

Projection of GHG Emissions into the Future

Once the GHG emissions for 2022 were calculated, the future emissions must be estimated through 2050. This was done through linear interpolation and extrapolation. First, the yearly VMT for each roadway type must be estimated into the future. The MnDOT VMT data provides historical VMT data yearly from 2001 onwards. Between 2008 and 2009, however, there was a major reclassification of roadways in the MnDOT system so there is a major jump or decrease in VMT for different roadway types. Therefore, data from 2009 onward was used.

For each roadway type, the data from 2009 to 2019 (2020-2022 were excluded due to the COVID-19 pandemic) was used to create a trendline which was then extended as the estimate of VMT through 2050. At this point it was noticed that the freeway roadway types exhibited unusual VMT trends, with VMT noticeably reducing on multiple roadway types. Due to these anomalies and discussions with Bloomington, it was chosen to move forward only analyzing city streets as these are the roadway networks that Bloomington has most direct control over.

This same basic process was used to estimate the changes in emissions per VMT year over year by developing the trendline between the 2022 emissions rates and the 2030 emissions rates already estimated in the EPA MOVES tool. This emission rate already included anticipated improvements in vehicle MPG (which directly causes reduced emissions). Therefore, this baseline incorporates reduced emissions due to increases in vehicle fuel efficiency. To calculate the total emissions for each future year, the estimated emissions rate per VMT of each future year was multiplied by the total estimated VMT for each future year.

In addition, total VMT loss due to COVID-19 was incorporated. For each roadway type that had not recovered to pre-pandemic VMT levels, the asymptotic percentage of maximum VMT was calculated. This indicates the total percentage of VMT that would remain after the pandemic (e.g., 80% of VMT was realized after the pandemic). This percentage was assumed to persist in perpetuity below the trendline calculated from the pre-pandemic VMT values. This developed a baseline trend for total GHG emissions through the year 2050.

Estimation of GHG Emissions Reductions

Finally, the emission reduction potential of various scenarios was calculated. The two key avenues identified through which emissions could be further reduced were VMT reduction and vehicle electrification. In both cases, they were estimated through a reduction of 'polluting VMT'. Therefore, these could be calculated as percentage reductions that can then be multiplied against the projected total GHG emitted to get the year over year total GHG emission reduction. VMT reductions must be considered first as this compounds upon the reduction felt by electrification. Multiple scenarios were developed to showcase potential reductions. Each scenario targeted an 80% total reduction of GHGs from 2022 levels. This value was chosen due to limitations in the modelling capabilities of estimating reductions due to electrification (explained in further detail below). It is assumed that the remaining 20% of emissions can be eliminated through a combination of renewable alternative fuels (such as hydrogen or bio-fuels) or carbon sequestration.

Each scenario used different combinations of VMT reduction and electrification to achieve this target. VMT reduction as a percentage was calculated by setting a VMT reduction target by 2050 (e.g. 10%, 20%, etc.). These values were selected to showcase a wide range of scenarios and are based off realistic targets set by other municipalities and the state. For each percentage level, it was assumed that VMT would be reduced linearly from 100% of 2022 VMT to the identified 2050 level (e.g. a 10% reduction by 2050 would correspond to 90% of VMT remaining in 2050, etc.). This extrapolated percentage for each year was multiplied by the total GHG produced to find a total amount of GHG reduced for each year.

Once the amount of GHG less VMT reductions was calculated, the remainder of the GHG to the 80% target was assumed to be reduced via electrification. To calculate the total GHG reduced year over year, the percentage of electric vehicle (EV) in the total vehicle fleet must be estimated, where EVs are assumed to produce zero 'polluting VMT'.

To model this, the purchasing rate of EVs must be identified. This can be calculated through a random replacement model, where the average service life of a vehicle can be used to estimate how often vehicles must be replaced. The average service life of vehicles was identified through the FHWA, and linear extrapolation was used to estimate the anticipated service life of vehicle through 2050. Note this random replacement model is the reason alluded to above that the 80% threshold was used; this model utilizes an exponential function to estimate the half-life of the vehicle fleet and determine the percentage of vehicle that turn over each year. Because of this, the mathematical model is incapable of ever reaching 100% vehicle turnover, meaning 100% GHG reduction can never be achieved according to the model. Of course, total carbon neutrality can be achieved, hence the assumption that the remainder of GHG emissions is reduced via other sources. Through this random replacement model, all that must be determined is the percentage of the fleet that is sold each year, that is an EV. To estimate this, it was assumed that 2022 had 0% EV sales and the fleet consisted of 0% EVs (to be conservative).

From there, it was assumed that EV sales percentage would increase linearly until a certain year (determined by the scenario) whereafter all new car sales are EVs. Through the random replacement model, this gives a total percentage of the fleet that is an EV. To calculate the total GHG reductions, it was assumed that the percentage of the fleet that was an EV directly corresponded to a percentage reduction of polluting VMT. Therefore, the GHG reductions were calculated in the same way as described above for VMT reduction where the percentage of polluting VMT reduced was multiplied by the total GHG produced for each year. This generated the total GHG reduction values for each year from 2022 through 2050.