TRANSPORTATION AND CLIMATE CHANGE: TRAVEL TRENDS AND GHG EMISSIONS

PART 1 OF 3

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PART 1

INTRODUCTION

This report is the first of three from a research initiative addressing how urban transportation can reduce climate change. This report provides a baseline on how transportation impacts greenhouse gas (GHG) emissions. The second report, "Public Transit and Climate Change," focuses specifically on the extent to which urban public transportation can help reduce GHG emissions. The final report in the series, "The Path Forward: Urban Mobility in a Climate-Sensitive Post-COVID World," explores the challenges and opportunities going forward as demographic, economic, technological, cultural, and political conditions evolve to influence urban transportation. It lays out the role transportation can play in meeting mobility needs and reducing GHG emissions. Thus, this report lays out foundational information that helps guide the observations and findings in the referenced subsequent reports. It also informs the broader understanding of the role of transportation in addressing climate challenges.

Policymakers are increasingly concerned about climate change. Increased scientific evidence, accumulating observations of weather and climate changes over time, changes in political leadership, and ever-increasing media attention to weather and climate phenomenon have engaged the public. Pew Research reports the share of Americans believing climate change is a major threat has increased from 44% in 2009 to 54% in 2022.[1]

1 Alec Tyson, Cary Funk, and Brian Kennedy, "What the data says about Americans' views of climate change," Pew Research Center, 2023. https://www.pewresearch.org/short-reads/2023/04/18/for-earth-day-key-facts-about-americans-views-of-climate-change-and-renewable-energy/ (accessed 18 April 2023).

As the single largest domestic GHG emissions-producing sector, transportation is inevitably a focus of climate change mitigation initiatives.[2] This attention is further enabled by the prospect of a path forward via focusing on a strategy based on electrification of vehicles, a transition to sustainable electricity production, and reliance on alternatives to personal vehicles for travel.

As climate impact moves up the ranks of evaluation criteria for virtually every transportation investment and policy decision, it is important to base these discussions on transportation's specific contribution to GHG emissions and the respective roles of person travel and freight across urban and rural geographies. It is also important to realize that transportation trends are evolving at a rate far greater than in the past several decades as changes in technology, demographics, and public priorities are influencing the amount, type and means of travel.

"Yet, today's transportation decisions and their impact on tomorrow's GHG emissions may not be well grounded in a rich understanding of travel behavior and transportation markets."

Yet, today's transportation decisions and their impact on tomorrow's GHG emissions may not be well grounded in a rich understanding of travel behavior and transportation markets. Much uncertainty remains regarding the phenomena of climate change, technology's effectiveness in mitigation, behavioral reactions to technology and policy initiatives, and unintended side effects. Both the magnitude of climate-protecting actions and the timeframe for their impacts to play out are critically relevant issues as transportation planners and policymakers weigh various policy and investment decisions going forward.

Most data in this report references pre-COVID conditions as a baseline for the discussion and analysis. These data are available and are most representative of the respective historic roles of passenger and freight transporation modes. Many analysts anticipate that there may be changes in the magnitude and shares of both passenger and freight mode

2 "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2019," US Environmental Protection Agency, https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2019 (accessed September 2024).

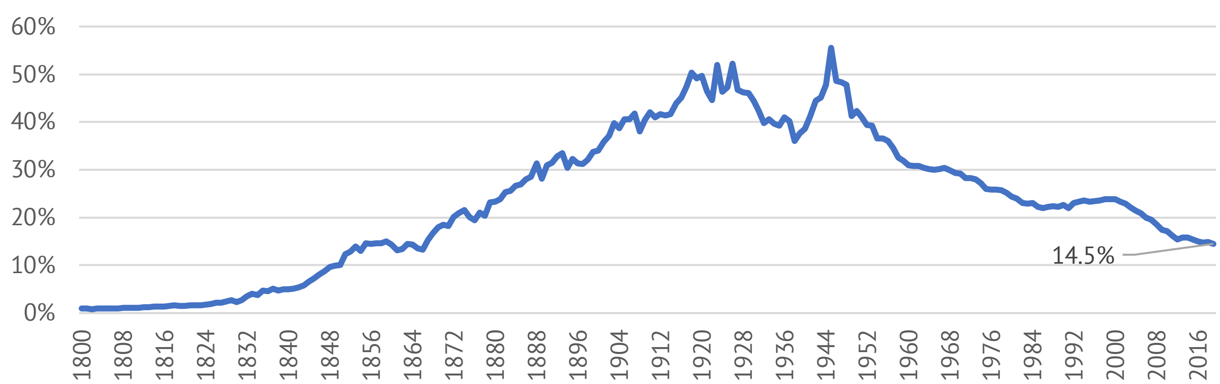
use in a post COVID-era and that trends such as differential rates of electrification of vehicles are likely to alter the relative GHG intensiveness of transportation market segments going forward.

PART 2

U.S. GREENHOUSE GASES IN PERSPECTIVE

Figure 1 shows the U.S. share of global CO_2 equivalent emissions since 1800.[3] Most notably, the U.S. share is back at the level that was estimated to have existed during the Civil War and is on a pronounced downward trend.

FIGURE 1: U.S. SHARE OF GLOBAL CO2 EQUIVALENT EMISSIONS, 1800-2019

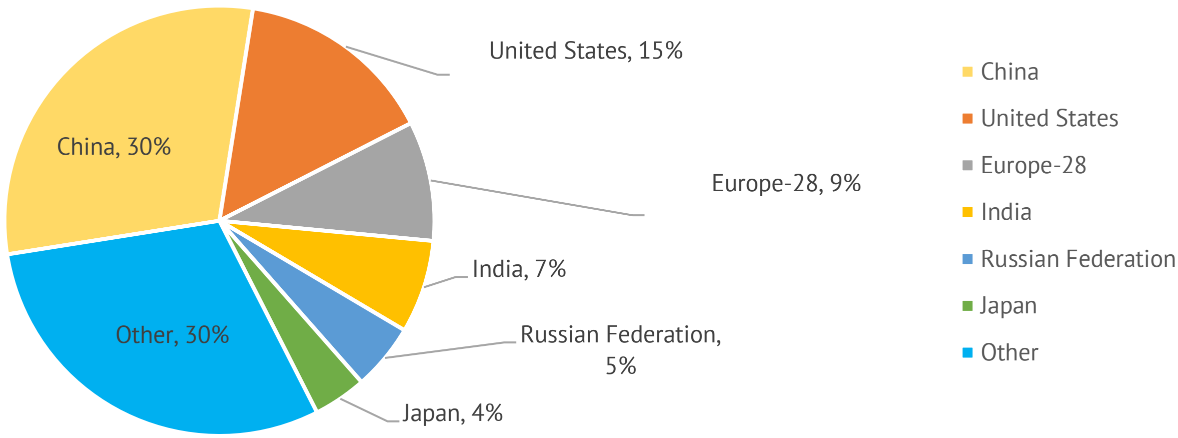


Source: Hannah Ritchie, Max Roser and Pablo Rosado, "CO2 and Greenhouse Gas Emissions," ourworldindata.org, Our World in Data. August 2020. https://ourworldindata.org/co2-and-greenhouse-gas-emissions (May 2023).

[3] Carbon dioxide equivalent or CO_{2e} means the number of metric tons of CO_2 emissions with the same global warming potential as one metric ton of another greenhouse gas. It is calculated using Equation A-1 in 40 CFR Part 98. CO_2 constitutes an estimated 80% of CO_2e (Overview of Greenhouse Gases | US EPA).

The U.S. contribution is less than a third of its peak share in the 1940s. Figure 2 shows the distribution across select countries in 2014.

FIGURE 2: 2014 CO2 EMISSIONS FROM FOSSIL FUEL COMBUSTION, CEMENT MANUFACTURING AND GAS FLARING



Source: Boden, T.A., Marland, G, and Andres, R.J. (2017). National CO2 Emissions from Fossil-Fuel Burning, Cement Manufacture, and Gas Flaring: 1751-2014, Carbon Dioxide Information Analysis Center, Oak Ridge National Cemetary, U.S. Department of Energyg, doi 10.3334/CDIAC/00001_V2017.

The share of CO_2 equivalent emissions attributable to the U.S. has declined by approximately 50% in the last 50 years, and this downward trend is expected to continue as population growth and economic activity, which drive energy use, are anticipated to increase in emerging economies. The same source shows the trend since 2019 continuing through the COVID era, declining to 13.5% of global emissions in 2021.[4] Other economies are not likely to be able or willing to move toward sustainable energy sources since many lack the resources, technology know-how, or political will. Thus, the significance of U.S. sustainability initiatives in terms of its emissions contribution to global trends, and even the merits and strategy for domestic investments in sustainability, need to be understood in the context of their global significance. These impacts go beyond the share of emissions, since U.S. actions can influence other countries, providing feedback on sucessful practices, and spurring development of technologies that can be deployed globally. Thus, U.S. initiatives and priorities should be evaluated in terms of both their quantitative impact and their global influence.

4 "United States: CO2 Country Profile," Our World in Data,, https://ourworldindata.org/co2/country/united-states?country=~USA#what-share-of-global-co2-emissions-are-emitted-by-the-country. 2019 data are used in the remainder of this report to be consistent with other data and to avoid any distortions that COVID may have had on relative trends.

Carbon emissions externalities are not limited to impacting persons within a buffer area but rather a local traveler's carbon emissions impact everyone across the globe.

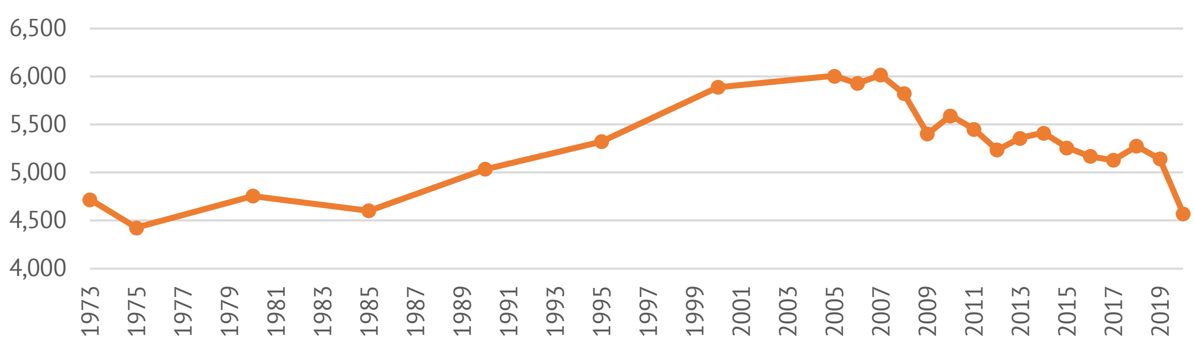
COVID Period Illustrates Volatility in Energy Trends

Total U.S. energy-related CO_2 emissions decreased by 11% in 2020, relative to 2019, mainly due to a short-term reduction in energy demand because of the COVID-19 pandemic. U.S. emissions related to petroleum product consumption, such as motor gasoline and jet fuel, decreased by 14% from the previous year. Consumption of both fuels decreased as a result of an increase in working from home and a decrease in travel demand during the COVID-19 pandemic. Warmer winter weather and continuing changes in the fuel mix of electricity generation, supported in 2020 by low natural gas prices, is the longer-term trend causing part of this decline. Emissions from coal generation declined by 19%, which is about the same change as from 2018 to 2019.

Source: "U.S. Energy-Related Carbon Dioxide Emissions: 2020," U.S. Energy Information Administration, eia.gov, December 2021. https://www.eia.gov/environment/emissions/carbon/index.php (December 2022).

Figure 3 shows total U.S. CO_2 emissions from energy consumption from 1990 to 2019. The CO_2 emissions attributable to energy use are relatively stable and have been trending down over the past decade—a trend not attributable to a declining population or a weak economy but rather one enabled by technological changes in the production and use of various energy sources and, arguably, policy initiatives.

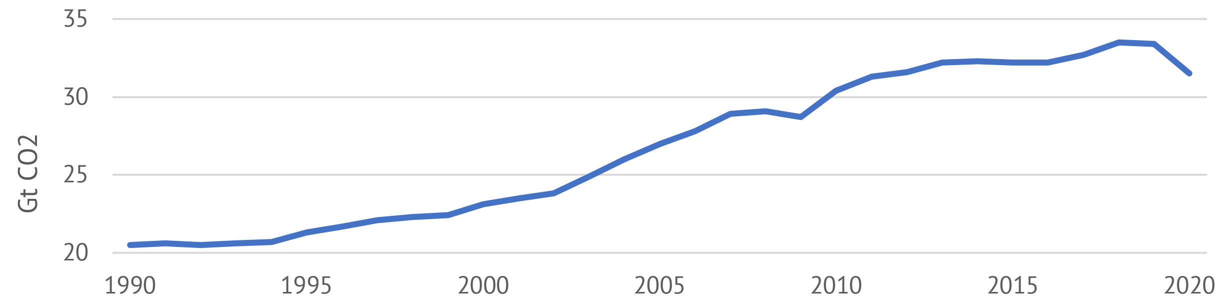
FIGURE 3: U.S. CARBON DIOXIDE EMISSIONS FROM ENERGY CONSUMPTION, MILLION OF METRIC TONS



Source: "Monthly Energy Review October 2021," US Energy Information Administration, eia.gov, October 2021. https://www.eia.gov/totalenergy/data/monthly/previous.php (May 2023).

While the U.S. is showing positive trends, the global trend in Figure 4 is less encouraging as one would deduce from seeing the declining U.S. share of global emissions in Figure 1. Except for the recessionary period in 2008 and 2009 and the COVID-19 impact in 2020, global emissions have been on an upward trend. (See Figure 4.)

FIGURE 4: GLOBAL ENERGY-RELATED CO_2 EMISSIONS, 1990-2020

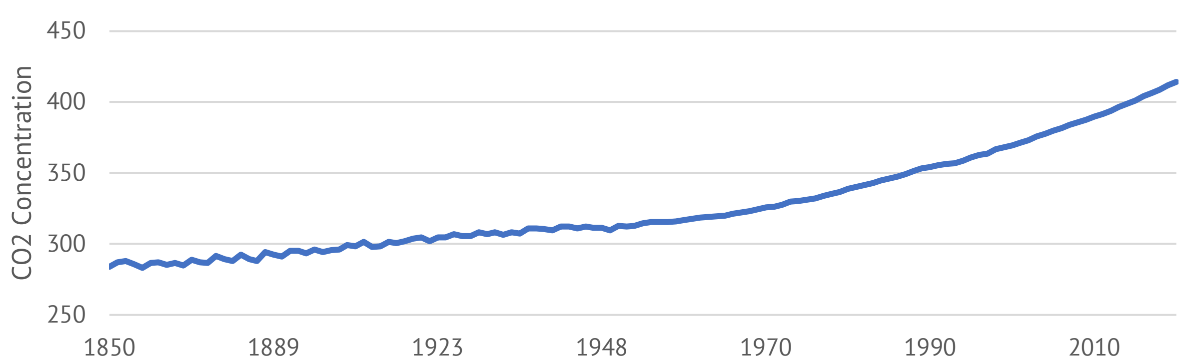


Source: "Global energy-related CO2 emissions, 1990-2000," International Energy Agency, iea.org, October 2022. https://www.iea.org/data-and-statistics/charts/global-energy-related-co2-emissions-1990-2020, (May 2023).

Domestic trends, while relatively positive compared to global numbers, have not been adequate to dampen global emissions or global concentration trends. If the 2019 estimate of 14.5% CO_2 emissions share attributable to the U.S. were to completely disappear, the total global energy-related CO_2 emissions levels would drop to approximately those of 2006.

The consequences of this upward trend are apparent in Figure 5, where atmospheric CO_2 concentrations are shown.

FIGURE 5: GLOBAL CO_2 CONCENTRATIONS, PPM, 1850-2020



Source: "Global Monthly Mean CO2" NOAA Global Monitoring Laboratory, gml.noaa.gov, 2023. https://gml.noaa.gov/ccgg/trends/global.html (May 2023).

Keep in mind that fossil fuel combustion carbon emissions are only part of total emissions, carbon emissions are only part of total GHG equivalent emissions, and manmade GHG emissions are only part of the total production and absorption of GHGs annually.[5] It is the CO_2 equivalent concentration levels that are ascribed importance in climate change.

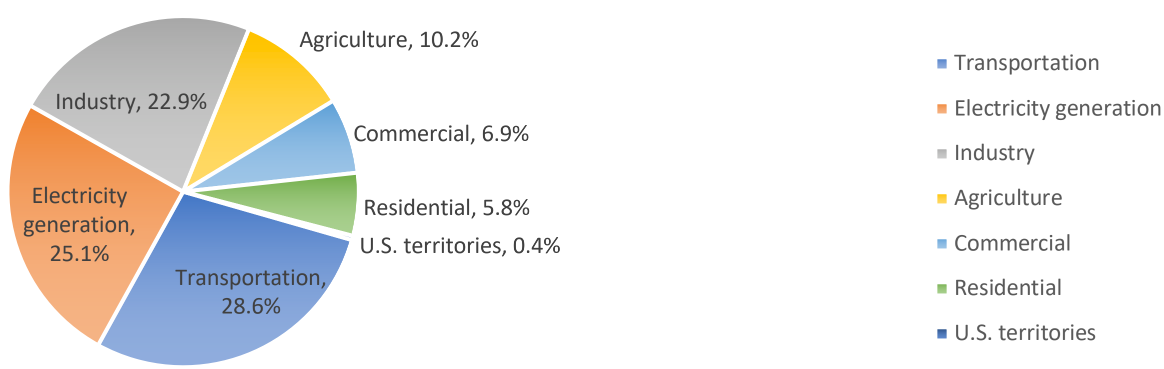
5 For example, non-CO_2 emissions constitute approximately 28% of all GHG equivalent emissions. Summary Report: Global Anthropogenic Non-CO2 Greenhouse Gas Emissions: 1990 - 2030 Revised December 2012 Office of Atmospheric Programs Climate Change Division U.S. Environmental Protection Agency.

PART 3

GREENHOUSE GASES CONTRIBUTIONS FROM TRANSPORTATION

Transportation is listed as the top contributor to U.S. emissions. Figure 6 portrays the typical categorization of the relative contributions of various sectors of the economy. US transportation constitutes 28.6% of U.S. CO2 equivalent emissions, or 4.15% of global CO2 equivalent emissions.

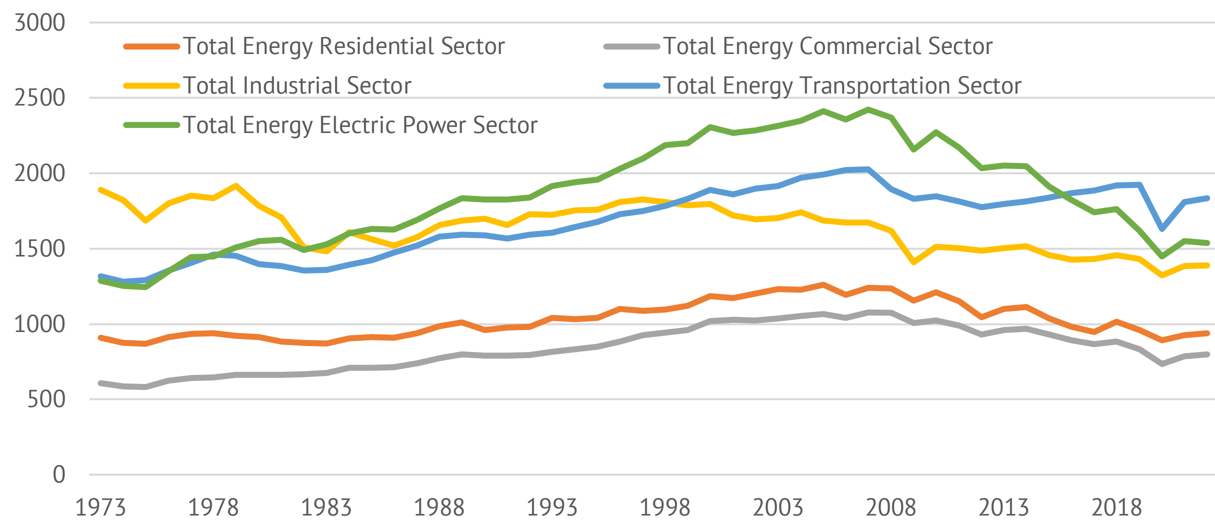
FIGURE 6: SHARE OF US GHG EMISSIONS BY SECTOR, 2019



Source: "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2019," U.S. Environmental Protection Agency, epa.gov, January 2023. https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2019 (April 2023).

Figure 7 shows the trends over time. Transportation has replaced electrical generation as the largest contributor of CO_2 emissions, with fuel mix shifts in both power generation and industry being primarily responsible for the declines in emissions shares by sector.

FIGURE 7: U.S. CARBON DIOXIDE EMISSIONS FROM ENERGY CONSUMPTION, MMT, 1973-2022



Source: "Monthly Energy Review May 2023," US Energy Information Administration, eia.gov, May 2023. https://www.eia.gov/totalenergy/data/monthly/ (May 2023).

The next step is to understand the distribution of emissions among transportation uses in order to consider how emissions reduction strategies may impact different market segments. That way, spending and resources can be devoted to initiatives that might provide the greatest benefit.

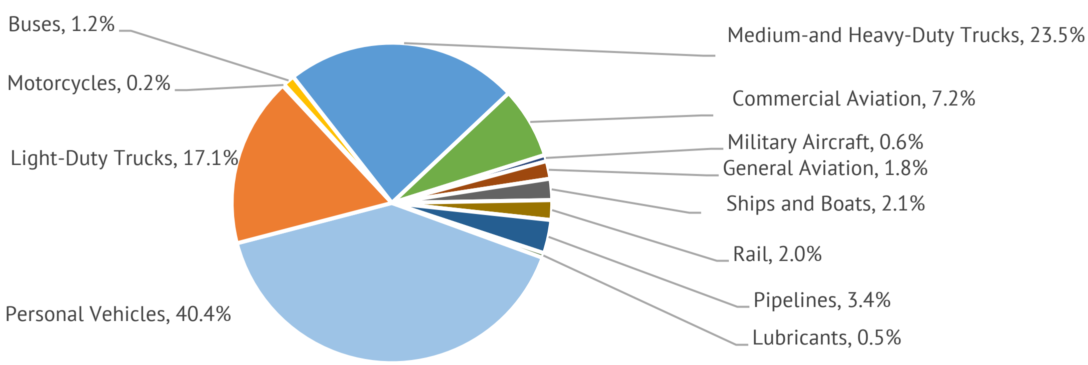
As expected, the global contributions of any single market segment are exceedingly modest, some small fraction of the 4.3% of global emissions attributable to U.S. transportation. This is not to pass judgment on the merits of decarbonization initiatives but to highlight the challenges in determining how to best direct resources and policies within transportation and between transportation and other sectors. Each individual action or behavior, even if deployed at the national level, is in essence *de minimus*. This can be discouraging to aspirations to make meaningful contributions to global GHG reductions. Thus, it's critical that the influence of individual actions, be they policies, investments, or other initiatives, contribute toward the policy goals as much as possible.

PART 4

GREENHOUSE GASES CONTRIBUTIONS FROM TRANSPORTATION MARKET SEGMENTS

Figure 8 shows U.S. emissions shares across transportation modes.

FIGURE 8 U.S. TRANSPORTATION MODE SHARES OF CO_2 EQUIVALENT EMISSIONS, 2019



Source: "Energy Consumption by Mode of Transportation," US Department of Transportation, Bureau of Transportation Statistics, bts.gov, 2021. https://www.bts.gov/content/energy-consumption-mode-transportation (April 2023).

Table 1 applies the domestic and global emissions proportions to the different modal segments to show the magnitude of significance across the market segments. The largest contributors of global emissions in transportation are light-duty, short-wheelbase (personal) vehicles. This U.S. market segment constitutes less than 2% of global GHG emissions. This segment is getting the most aggressive attention in transitioning to less-carbon-intensive electric vehicles because smaller vehicles are cheaper, have battery capacities that provide reasonable travel range, and can be recharged at home. While electrification of other surface modes is under development, progress lags in heavy vehicles due to technology and economic considerations. Within the light vehicles market segment, climate-concerned policymakers believe consumers might be partially shifted to public transportation or alternative modes.

TABLE 1: APPROXIMATE SHARES OF GHG EQUIVALENT EMISSIONS

Market Segment	Percent of U.S. Transportation Emissions	Percent of U.S. GHGe Emissions	Percent of Global GHGe Emissions
Personal Vehicles	40.4%	11.55%	1.68%
Light-Duty Trucks	17.1%	4.89%	1.40%
Medium-and Heavy-Duty Trucks	23.5%	6.72%	1.92%
Air	9.6%	2.75%	0.79%
Pipeline	3.5%	1.00%	0.29%
Water	2.0%	0.57%	0.16%
Rail	2.1%	0.60%	0.17%
Buses	1.1%	0.31%	0.09%

Source: Derived from data in Figures 8 (column 2), Figure 1 (U.S. share factor, column 3), and Figure 6 (transportation sector share, column 4).

Additional insight into travel market segments can be gleaned from data on the distribution of vehicle miles of travel (VMT) across market segments. Table 2 shows an estimate of total roadway VMT across some market segments. This data, developed from the National Household Travel Survey (NHTS) and federal estimates of VMT, shows the share of total household roadway travel. The table reveals two relevant points. First, based on the available 2017 data, household-based travel comprised approximately 70% of the VMT on the roadways. Nevertheless, household vehicles comprise a far smaller share of energy use and emissions production than heavy trucks and commercial vehicles since household vehicles are generally lighter, smaller, and more energy efficient.

TABLE 2: ESTIMATES OF VEHICLE MILES OF TRAVEL BY SELECT MARKET SEGMENTS

	2009		2017	
Percent of Household VMT	**Percent of Household VMT**	**Percent of all Roadway VMT**	**Percent of Household VMT**	**Percent of all Roadway VMT**
Household Travel[1]				
Commuting	27.8%	76%	30.2%	70.4%
Work Related/Business	9.0%		3.2%	
Other Household Travel	63.2%		66.6%	
Subtotal	100%		100%	
Public and Commercial Travel				
Public Vehicle Travel		2%[2]		20.5%
Utility/Service/Commercial Travel		12%[3]		
Heavy freight and goods[4]		10%		9.1%
Total		100%		100%
Total VMT	2.956 trillion		3.212 trillion	

Sources: "National Household Travel Survey," Federal Highways Administration, www.fhwa.dot.gov, 2018. https://nhts.ornl.gov/ (April 2023). "Travel Monitoring: Traffic Volume Trends," Federal Highways Administration, www.fhwa.dot.gov, March 2023. https://www.fhwa.dot.gov/policyinformation/travel_monitoring/tvt.cfm (April 2023).
[1]FHWA estimate based on NHTS data.
[2]FHWA estimate using vehicle registration data.
[3]FHWA estimate based on HPMS data and NHTS.
[4]FHWA estimate based on HPMS data.

Second, and even more important, household-based travel has been a declining share of the total VMT on the roadway system. The evolution of a more service-centric economy with ever larger shares of services and products being *procured* rather than performed by household members has generated larger amounts of travel by service vehicles delivering products and transporting service workers to homes and businesses to carry out a multitude of services. The 2022 NHTS data indicates that travel by households for household-serving purposes is continuing to decline as a share of all travel.

The Vehicle Inventory and Use Survey (VIUS), carried out in 2022 by the Census Bureau for the U.S. Department of Transportation, provides greater insight into non-auto vehicle travel. Analysis of trip purposed for those light vehicles may give insight into personal household serving trips versus work-related travel for those vehicle classes. Much of the commercial and service mileage is also carried out in light-duty vehicles. Police cars, for example, and an array of business and agency vehicles are also light vehicles. There is a high probability that these trips are not conducive to being shifted to public transportation or other modes. Thus, the share of energy used by light vehicles referenced in Table 2 is not all carried out by travelers who can self-determine their travel modes. These trips are also far less likely to be trips amenable to alternative modes because they involve chained trips and include transport of materials or equipment.

More market insights may be gleaned by exploring travel distribution between urban and rural areas. Specifically, rural areas are not very conducive to using public transit for emissions-efficient mobility due to the low densities. Types of public transportation services do serve some rural areas, but these areas are not generally able to turn to public transit as a strategy to reduce emissions. Long-distance travel does have competition between private vehicles, intercity bus, and rail and airline travel for some origin-destination pairs.

Various federal agencies use different definitions of rural areas, and these geographies are updated in response to changes in urbanization. Two relevant sources are the Federal Highway Administration's (FHWA) traffic volume reports and the U.S. DOT's geographic classification of trip makings, as reported in the NHTS. Table 3 shows the allocation of mileage between urban and rural areas as reported based on travel volumes. This shows VMT by roadway classification for the 12 months immediately prior to COVID and for the corresponding 12 months in 2021 and early 2022, a time where the most severe COVID impacts were moderated but COVID-induced behavior changes were still apparent.

TABLE 3: VEHICLE TRAVEL ON U.S. ROADWAYS: INDIVIDUAL MONTHLY VEHICLE-MILES OF TRAVEL IN BILLIONS

System	March 2019-February 2020, Pre-COVID	March 2021-February 2022	Percent Change
Rural Interstate	262.5	271.4	3.4%
Rural Other Arterial	385.1	394.3	2.4%
Other Rural	339.3	351.3	3.5%
Rural Total	986.9	1,017.0	3.0%
Rural Share of Total	30.2%	31.2%	
Urban Interstate	576.9	563.6	-2.3%
Urban Other Arterial	1,158.2	1,132.6	-2.2%
Other Urban	547.4	546.2	-0.2%
Urban Total	2,282.5	2,242.4	-1.8%
Urban Share of Total	69.8%	68.8%	
All Systems	3,269.5	3,259.4	-0.3%

Source: "Travel Monitoring: Traffic Volume Trends," Federal Highways Administration, www.fhwa.dot.gov, March 2023. https://www.fhwa.dot.gov/policyinformation/travel_monitoring/tvt.cfm (April 2023).

The share of traffic on rural roads is approximately 30% and increased 1% in share between these periods. A faster rebound for truck travel, diversion of long-distance travel from plane to personal vehicles, and dispersion of travel to less dense areas contributed to this shift in travel. These numbers represent the mileage accumulated on rural road segments as enumerated by FHWA data. The increase in rural share is consistent with the decline in urban commuting and dispersion of activities away from urban cores, as well as catch-up, and longer-distance travel as COVID's strictest restrictions were relaxed. The urban market, now less than 70% of all roadway travel, is the segment that might be the primary target for increased public transit services, micromobiltiy options, and shared services.

Tables A-1 and A-2 in Appendix A show additional classifications of travel by geography and by vehicle occupancy. The data, from the 2017 NHTS, is assigned based on the location of the trip origin. In this data set, the share of trips from rural areas is 14.3% of vehicle trips and 14.7% of person trips (Table A-1). The share of rural travel by vehicle miles is 20.8%, reflecting the longer trip lengths. Longer trips also tend to have slightly higher average vehicle occupancies, about 0.2 to 0.3 persons per vehicle mile higher.

The tables also show the distribution of vehicle occupancies by trip length and non-rural/rural classification. Conversion of higher-occupant personal vehicle trips to other modes is both more challenging and provides little or no environmental benefit. The economic motivations to shift to purchased service are similarly diminished for group trips as the alternative modes' costs would typically be incurred by each traveler versus the distributed cost of auto use over multiple occupants.

Most telling in Table A-2 is the data indicating that 31.7% of all passenger miles are incurred in trips over 40 miles in length. There are few locations in this country, there are opportunities to take 40+ mile transit trips (e.g., on commuter rail). However, most of these trips are unlikely to be able to be addressed by transit solutions because the density of users at such distances is so low the cost per trip would be very, very high. In total, all trips over 40 miles (31.7%) plus all rural trips less than 40 miles (12.8%) are low probability trips for addressing with public transit or bike or walk strategies due to very high costs or travel times. Thus. 44.5% of passenger miles are largely unsuitable targets for transit service. One could similarly postulate that the remaining trips with three or more passengers, 8.2%, would be very low-priority opportunities as they are harder to attract and unlikely to offer emissions benefits (at least at a point in time when all options are electrically propelled). Thus, 47.3% of trips may be candidates for potential conversion to transit.

Table 4 characterizes the breakdowns in market segments. U.S. non-rural travel in one- and two-person vehicle trips of 40 or less miles constitutes less than one percent of global emissions. The characteristics of this market segment give insight into the strategies that could influence emissions.

TABLE 4: EMISSIONS REDUCTION OPPORTUNITY BASED ON TRAVEL MARKET SEGMENTS

U.S. GHGe Emissions as Share of Global Emissions	--	= 14.5%
Transportation Emissions as Share of U.S. Emissions	28.6% x 14.5%	= 4.15%
Light Vehicle Travel Share of Transportation Emissions	40.4% x 4.15%	= 1.68%
Market Opportunity Based on Urban, One and Two Passenger Light Vehicle Trips 40 or Less Miles Long	47.3% x1.68%	= 0.79%

Another way to look at market segments of travel is to review the volume of travel by trip purpose. Different trip purposes have characteristics that may make them good targets for different strategies that might influence mode or GHG emissions. For example, work trips are typically single occupant, recurring trips, often during congested periods, and incur parking costs. Hence, they are more conducive to shifting to public transportation. Time of day, the criticality of on-time arrivals, whether materials or items need to be transported, group size, and other factors may influence the willingness to consider various travel options.

Also, different trip purposes may be perceived as having different value and might motivate different policies and strategies. A colleague once noted how his most important trip was a regular trip to an assisted living facility to play dominoes with his grandmother; reminding one that policy makers should use caution in attempting to differentially influence travel based on judgments on the importance of different trip purposes. Nonetheless, work trips have tended to be given greater attention in terms of transportation planning and policy.

Table 5 uses VMT by trip purposes from the NHTS as a means of showing the shares of vehicle travel by the aggregation of trip purposes the NHTS uses. Work trips constituted the largest single category at about 30% of all VMT in 2017. Work trips' share of VMT is higher than its share of the trip count as work trips are, on average, longer and have lower average occupancy. Work trips are often important considerations in transportation planning and policy as they define peak periods and are responsible for much of the congestion that exists. Work trips were also the largest share of transit trips, with various estimates ranging from 35 to 60% of all transit trips being work or work-related pre-COVID. Work trips have historically been the focus of travel demand management initiatives and the priority market for public transportation.

TABLE 5: TRIP PURPOSE MARKET SEGMENTS AVERAGE ANNUAL VMT PER HOUSEHOLD

Trip Purpose	All Purposes	To / From Work	Shopping	Other Family / Personal Errands	Social / Recreation	Other
NHTS adjusted 2017	19,642	5,774	2,920	3,325	4,826	2,797
Share		29.4%	14.9%	16.9%	24.6%	14.2%
Share with +15% telework		26.1%	15.6%	17.7%	25.7%	14.9%
Share with +15% telework and mileage redeployed to other purposes		25.0%	15.8%	18.0%	26.1%	15.1%

Source: "Summary of Travel Trends 2017 National Household Travel Survey," Federal Highways Administration, www.fhwa.dot.gov, July 2018. https://nhts.ornl.gov/assets/2017_nhts_summary_travel_trends.pdf (April 2023). From Table 6a of "Trends in the Average Annual Vehicle Miles of Travel by Selected Trip Purposes."

The recent dramatic change in participation in work-at-home/work-from-home or telework has dramatically altered the commute market. The third row in Table 5 shows a redistribution of the trip purpose shares if the telework share is sustained at near its current level. Approximately 6-8% of workers pre-COVID worked at home, but levels have been running in the mid-20s to 30% in recent surveys.[6] The fourth row of Table 5 shows the trip purpose shares if the time and money saved in not commuting is redeployed proportionally on other travel. As shown in Table 3, total VMT is nearly at the same level as before COVID, suggesting some redeployment of those miles across market segments (freight, commercial, household) and trip purposes. Table 6 characterizes each trip purpose in terms of its impact on global GHG emissions. As the shares reaffirm, the impacts of addressing any given market segment are extremely modest in the context of the global challenge.

TABLE 6: GLOBAL EMISSIONS BY U.S. VEHICLE TRIP PURPOSE SEGMENTS

Trip Purpose	All Purposes	To / From Work	Shopping	Other Family / Personal Errands	Social / Recreation	Other
Share of Global GHG Emissions	1.68%	0.42%	0.27%	0.3%	0.44%	0.25%

Source: Based on data from Table 4 and Table 5, row 4.

[6] See https://wfhresearch.com/ for data on telework trends.

PART 5

EVOLVING TRAVEL TRENDS

Historically, travel behavior has changed slowly because land use patterns, technologies, existing infrastructure, and behaviors change relatively slowly. The most significant change in travel trends in the past several decades has been the pronounced impact of the COVID-19 pandemic influencing telework and communication substitutions for travel.[7] This is significant because many of these behavior changes are having residual influence after the pandemic. This should not be overlooked in transportation planning and policy, as it emphasizes a newer, now more competitive travel choice–the choice to not travel and instead carry out activities virtually. This choice provides a transportation emissions-free option.

There is an opportunity to leverage increasingly sophisticated technologies to carry out ever more activities virtually, providing a powerful, potentially win-win strategy to reduce travel emissions. It is certainly prudent to find ways to substitute communication for travel, particularly for tasks where travel is onerous. In addition to telework, online learning, online worship, telemedicine, online banking and business transaction, secure document transmittal, and other activities are increasingly being carried out without travel. While the extent of return-to-the-office behaviors remains uncertain, over time, enhanced software

7 Hilary Silver, "Working from Home: Before and After the Pandemic." *Contexts*, *22*(1), 2023, 66-70. https://doi.org/10.1177/15365042221142839

and hardware for virtual connections, the aging out of generations who are technology-reluctant, and greater acceptance by governments and businesses of virtual means of conducting business are likely to result in continued growth in the substitution of communications for travel.

> *There is an opportunity to leverage increasingly sophisticated technologies to carry out ever more activities virtually, providing a powerful, potentially win-win strategy to reduce travel emissions.*

As has been evident by the pronounced impact of telecommuting on public transportation, these substitution effects can have differential impacts across market segments. More specifically, the reduction in work commuting has been pronounced and creates the need for transportation plans and policies to reorient to a higher share of other travel purposes and different policy tools to match.

A second trend that merits watching and consideration in the context of emissions reduction strategies has been the shift in travel from households to commercial sectors. As shown in Table 2, there has been significant growth in commercial and service vehicle travel. Increasingly, people are having goods and services delivered to their home rather than driving to shopping venues. Everything from home health care, house-cleaning, lawn, pool, and bug services, dog-walking, meal delivery, and package delivery, etc., collectively reduce trip-making by household members by outsourcing the travel to commercial providers. This has contributed to the declining household trip rates that have been evidenced over the past several NHTS cycles. This phenomenon has implications in terms of targeting strategies for deploying technology and other means of influencing emissions.

A third trend to consider is the growth in recreational travel. COVID reduced social travel for numerous months, and demand has since rebounded significantly.[8] That near-term "make-up or revenge" travel trend overlays other trends, such as growing international tourism, the large baby boom generation retiring and anticipating significant travel in retirement, and younger generations indicating a preference for investing in life

[8] U.S. Travel Association, "Travel Forecast," January 17, 2024, https://www.ustravel.org/research/travel-forecasts.

experiences rather than material goods. Some segments of this social recreation travel have characteristics that may require different strategies and be less subject to typical travel demand influencing initiatives. These trips are less conducive to service by traditional public transit options. Similarly, promotion of bike and walk options or electric vehicle adaptation may be less relevant for social recreation trips that tend to have longer trip lengths and larger group sizes and dispersed destinations.

A fourth trend to watch is the change in the geographic distribution of the residential population. Changes in the urban, suburban, and fringe population distribution can influence the nature of travel and whether travelers will respond to various policies, investments, and technologies.[9] It is also relevant at the national scale, where differential growth trends impact transportation needs and opportunities. COVID has been credited with increasing dispersion of the urban population, which may be further encouraged by housing affordability and urban crime sensitivities. Large urban areas that have historically had higher densities and higher levels of transit service and use, shorter trips and greater conduciveness to bike and walk travel, tend to be losing population to southern metropolitan areas with lower densities, less mature and viable public transportation options, and settlement patterns and infrastructure less conduciveness to bike or walk options[10]

In general, there is significant variation in demographic trends and post-COVID travel and activity patterns across geographies. Understanding context-specific conditions, as well as affirmation of post-COVID behaviors as time passes, may provide greater insight into travel demand conditions.[11, 12] These variations and insights may shape the appropriate strategies for meeting those needs in a given context while striving to reduce emissions.

Electrification and automation are two technology trends that will significantly influence transportation's future. The pace of electrification across the modes will influence the

9 Peter Haslag, Daniel Weagly, "From L.A. to Boise: How Migration Has Changed During the COVID-19 Pandemic," *Journal of Financial and Quantitative Analysis*, no. 5 (2024): 2068–98. https://doi.org/10.1017/S002210902300073X.

10 "U.S. Population Trends Return to Pre-Pandemic Norms," US Census Bureau, December 19, 2023, https://www.census.gov/newsroom/press-releases/2023/population-trends-return-to-pre-pandemic-norms.html#:~:text=DEC.,by%20the%20U.S.%20Census%20Bureau ; Thomas B. Foster, Lee Florio, Mark Ellis "Internal Migration in the U.S. During the COVID-19 Pandemic" U.S. Census Bureau, September 2024, https://www.census.gov/library/working-papers/2024/adrm/CES-WP-24-50.html; "New census data shows huge spike in movement out of big metro areas during the pandemic," William H. Frey, Brookings, April 14, 2022, https://www.brookings.edu/articles/new-census-data-shows-a-huge-spike-in-movement-out-of-big-metro-areas-during-the-pandemic/.

11 "Downtowns Rebound: The data driven Path to Recovery," Center City District Report 2023.

12 "The Fastest-Growing and Declining Cities Across the U.S. [2023]," Josh Koebert, Finance Buzz, October 2023.

competitiveness of those modes with respect to environmental impacts. The pace of electrification of personal automobiles may undermine the environmental advantage that might be claimed by electrified public transportation. Thus, the pace of electrification across modes will be relevant in influencing behaviors and impacts.

The pace of electrification across the modes will influence the competitiveness of those modes with respect to environmental impacts. The pace of electrification of personal automobiles may undermine the environmental advantage that might be claimed by electrified public transportation.

Automation of personal vehicles has been researched for its potential environmental impact and how it might influence total travel demand.[13] As automated vehicles are anticipated to be electric, they may offer near-term environmental advantages depending upon the pace of the electrification of personal vehicles. There remains uncertainty regarding the additional VMT that might be generated by the deployment of automated vehicles, whether through mobility-as-a-service strategies and/or through personal ownership. Concerns center around the extent of "deadhead" or empty miles traveled as unoccupied automated vehicles travel between customers. Future research and experience will shed light on how this might influence strategies for reducing GHG emissions in transportation.

Related to automation is the issue of sharing rides. Many visions of future mobility are reliant on the expectation of sharing rides in vehicles as a method of minimizing emissions and congestion. COVID dampened the willingness to share rides with strangers, and fear of crime and other factors relating to convenience, travel time reliability, and personal

13 WenWen Zhang, Subhrajit Guhathakurta, Elia Khalil, "The impact of private autonomous vehicles on vehicle ownership and unoccupied VMT generation," *Transportation Research Part C: Emerging Technologies*, Volume 90, 2018, 161, https://journals.scholarsportal.info/details/0968090x/v90icomplete/156_tiopavvoauvg.xml.

comfort appear to be significant challenges to broad acceptance of shared vehicle travel, at least under current conditions.[14]

Finally, the fifth trend to watch is changes in production and manufacturing of goods that may be influencing the share of domestic VMT associated with these activities. It is premature to know how this will play out, but if the interest in resilient supply chains, multisource procurement strategies, and domestic source preferences persists, it may result in larger shares of product production/manufacturing being carried out domestically, which in turn could change both the volume and travel patterns of domestic goods movement with subsequent domestic emissions impacts.

[14] Haotian Su,et. al., "Exploration of Factors That Influence Willingness to Consider Pooled Rideshare", *Transportation Research Record*, 2678:8, 2024, 57-73, https://journals.sagepub.com/doi/10.1177/03611981231213650?icid=int.sj-challenge-page.citing-articles.363.

PART 6

CONCLUSION

As transportation policy and investment decisions are increasingly shaped by desires to reduce GHG emissions, we need a foundational understanding of the contribution to emissions of the various transportation market segments. This knowledge can assist in prioritization and evaluation of the relative viability and value of various investments or policies.

It is also clear that domestic initiatives alone will not be meaningful in the absence of actions by other countries. Domestic decisions and actions will inevitably be models for consideration by other entities. Thus, efficient and effective initiatives in the United States will help inform international efforts. Many countries do not have the same level of resources or political will and will not be in a position to pursue marginally effective strategies. Similarly, domestic initiatives will not remain politically or financially sustainable absent a keen sensitivity to both effectiveness and affordability. As such, rigorous evaluation of decisions on policies and investments will be critical to prudent decision-making. This evaluation will require careful consideration of the cost-effectiveness of the respective initiatives; an up-to-date and objective analysis of the size of the target market segments; the effectiveness of the respective strategies; and the consequences across the full spectrum of relevant performance metrics of the proposed actions. The companion reports, “Public Transit and Climate Change,” and “The Path Forward: Urban Mobility in a Climate-Sensitive Post-COVID World,” explore the challenges and opportunities going forward as demographic, economic, technological, cultural, and political conditions evolve to influence urban transportation.

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APPENDIX A: VEHICLE TRIPS BY TRIP LENGTH AND VEHICLE OCCUPANCY

TABLE A-1: PERCENT OF VEHICLE TRIPS BY TRIP LENGTH AND VEHICLE OCCUPANCY (WEIGHTED, MILLIONS ANNUALLY)

ALL										Total	
Trip Distance	**Trips**	**Percent**	**Percent of All**	**Trips**	**Percent**	**Percent of All**	**Trips**	**Percent**	**Percent of All**	**Trips**	**Percent of All**
0-1	17,850	12.9%	8.2%	7,168	14.0%	3.3%	3,922	13.7%	1.8%	28,940	13.2%
1-2	20,921	15.1%	9.6%	8,433	16.4%	3.9%	4,442	15.5%	2.0%	33,796	15.4%
2-5	38,201	27.5%	17.5%	14,864	29.0%	6.8%	8,236	28.7%	3.8%	61,300	28.0%
5-10	26,517	19.1%	12.1%	9,506	18.5%	4.3%	5,439	18.9%	2.5%	41,462	18.9%
10-20	21,192	15.3%	9.7%	6,346	12.4%	2.9%	3,596	12.5%	1.6%	31,134	14.2%
20-40	10,638	7.7%	4.9%	3,107	6.1%	1.4%	1,712	6.0%	0.8%	15,456	7.1%
40+	3,552	2.6%	1.6%	1,888	3.7%	0.9%	1,364	4.8%	0.6%	6,805	3.1%
Total	138,871	100.0%	63.4%	51,311	100.0%	23.4%	28,711	100.0%	13.1%	218,893	100.0%
NON-RURAL	One Occupant			Two Occupants			Three or more Occupants			Total	
0-1	15,427	12.9%	7.0%	6,225	14.1%	2.8%	3,372	14.0%	1.5%	25,024	11.4%
1-2	19,251	16.1%	8.8%	7,801	17.7%	3.6%	4,110	17.0%	1.9%	31,163	14.2%
2-5	34,395	28.8%	15.7%	13,408	30.5%	6.1%	7,333	30.4%	3.3%	55,136	25.2%
5-10	22,427	18.8%	10.2%	7,893	17.9%	3.6%	4,360	18.1%	2.0%	34,680	15.8%

NON-RURAL	One Occupant			Two Occupants			Three or more Occupants			Total	
10-20	17,062	14.3%	7.8%	4,992	11.3%	2.3%	2,633	10.9%	1.2%	24,687	11.3%
20-40	8,261	6.9%	3.8%	2,327	5.3%	1.1%	1,316	5.5%	0.6%	11,903	5.4%
40+	2,655	2.2%	1.2%	1,355	3.1%	0.6%	987	4.1%	0.5%	4,996	2.3%
Total	119,477	100.0%	54.6%	44,000	100.0%	20.1%	24,111	100.0%	11.0%	187,589	85.7%
RURAL	One Occupant			Two Occupants			Three or more Occupants			Total	
0-1	2,424	12.5%	1.1%	943	12.9%	0.4%	550	12.0%	0.3%	3,916	1.8%
1-2	1,670	8.6%	0.8%	632	8.6%	0.3%	331	7.2%	0.2%	2,633	1.2%
2-5	3,806	19.6%	1.7%	1,456	19.9%	0.7%	903	19.6%	0.4%	6,164	2.8%
5-10	4,090	21.1%	1.9%	1,613	22.1%	0.7%	1,079	23.5%	0.5%	6,782	3.1%
10-20	4,129	21.3%	1.9%	1,354	18.5%	0.6%	963	20.9%	0.4%	6,446	2.9%
20-40	2,377	12.3%	1.1%	780	10.7%	0.4%	396	8.6%	0.2%	3,553	1.6%
40+	898	4.6%	0.4%	534	7.3%	0.2%	378	8.2%	0.2%	1,809	0.8%
Total	19,394	100.0%	8.9%	7,311	100.0%	3.3%	4,600	100.0%	2.1%	31,305	14.3%

Notes: In trip distance categories, upper bounds are included whereas lower bounds are excluded. The non-rural/rural distinction is made based on the NHTS OBHUR variable, non-rural is all categories other than rural.
Source: Analysis of FHWA 2017 NHTS data.

TABLE A-2: PERCENT OF VMT BY TRIP LENGTH AND VEHICLE OCCUPANCY (WEIGHTED, BILLIONS ANNUALLY)

ALL	One Occupant			Two Occupants			Three or more Occupants			Total	
Trip Distance	**VMT**	**Percent**	**Percent of All**	**VMT**	**Percent**	**Percent of All**	**VMT**	**Percent**	**Percent of All**	**VMT**	**Percent of All**
0-1	10.4	0.8%	0.5%	4.2	0.8%	0.2%	2.4	0.7%	0.1%	16.9	0.8%
1-2	31.0	2.5%	1.5%	12.5	2.4%	0.6%	6.5	2.1%	0.3%	50.1	2.4%
2-5	125.8	10.1%	6.0%	49.0	9.4%	2.4%	27.0	8.5%	1.3%	201.7	9.7%
5-10	189.7	15.2%	9.1%	67.6	13.0%	3.2%	38.8	12.3%	1.9%	296.1	14.2%
10-20	299.5	24.1%	14.4%	88.5	17.0%	4.3%	50.8	16.0%	2.4%	438.7	21.1%
20-40	285.2	22.9%	13.7%	85.6	16.5%	4.1%	46.3	14.6%	2.2%	417.2	20.0%
40+	302.8	24.3%	14.6%	212.8	40.9%	10.2%	144.7	45.7%	7.0%	660.3	31.7%
Total	1,244.4	100.0%	59.8%	520.1	100.0%	25.0%	316.5	100.0%	15.2%	2,080.9	100.0%
NON-RURAL	One Occupant			Two Occupants			Three or more Occupants			Total	
0-1	9.1	0.9%	0.4%	3.7	0.9%	0.2%	2.1	0.9%	0.1%	14.8	0.7%
1-2	28.6	2.9%	1.4%	11.6	2.8%	0.6%	6.1	2.6%	0.3%	46.2	2.2%
2-5	112.8	11.3%	5.4%	43.9	10.7%	2.1%	23.9	10.1%	1.1%	180.5	8.7%
5-10	159.9	16.0%	7.7%	55.8	13.6%	2.7%	31.0	13.1%	1.5%	246.7	11.9%
10-20	241.1	24.1%	11.6%	69.5	16.9%	3.3%	37.4	15.8%	1.8%	348.0	16.7%
20-40	220.4	22.0%	10.6%	63.7	15.5%	3.1%	35.4	14.9%	1.7%	319.4	15.3%
40+	229.6	22.9%	11.0%	162.8	39.6%	7.8%	101.1	42.7%	4.9%	493.5	23.7%
Total	1,001	100.0%	48.1%	411	100.0%	19.7%	237	100.0%	11.4%	1,649.1	79.2%
RURAL	One Occupant			Two Occupants			Three or more Occupants			Total	
0-1	1.3	0.5%	0.1%	0.5	0.5%	0.0%	0.3	0.3%	0.0%	2.1	0.1%
1-2	2.5	1.0%	0.1%	0.9	0.8%	0.0%	0.5	0.6%	0.0%	3.9	0.2%
2-5	13.0	5.3%	0.6%	5.1	4.6%	0.2%	3.1	3.9%	0.2%	21.2	1.0%

RURAL	One Occupant			Two Occupants			Three or more Occupants			Total	
5-10	29.8	12.3%	1.4%	11.8	10.8%	0.6%	7.8	9.8%	0.4%	49.4	2.4%
10-20	58.4	24.0%	2.8%	19.0	17.4%	0.9%	13.4	16.8%	0.6%	90.8	4.4%
20-40	64.9	26.7%	3.1%	21.9	20.1%	1.1%	11.0	13.8%	0.5%	97.8	4.7%
40+	73.2	30.1%	3.5%	50.0	45.8%	2.4%	43.6	54.8%	2.1%	166.8	8.0%
Total	243	100.0%	11.7%	109	100.0%	5.3%	80	100.0%	3.8%	431.8	20.8%

Notes: In trip distance categories, upper bounds are included whereas lower bounds are excluded. The non-rural/rural distinction is made based on the NHTS OBHUR variable, non-rural is all categories other than rural.
Source: Analysis of FHWA 2017 NHTS data.