Freedom to Move

Investing in Transportation Choices for a Clean, Prosperous, and Just Future

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Technical Appendices

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October 2024

www.ucsusa.org/resources/freedom-move
https://doi.org/10.47923/2024.15594

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Appendix A: Benefits of More Transportation Choices

The modeling framework for evaluating the benefits of the Net Zero/Low VMT Reduction and Net Zero/High VMT Reduction scenarios builds from previous UCS analysis in Clemmer et al.'s 2023 report *Accelerating Clean Energy Ambition* (ACEA), which builds from the modeling of Evolved Energy Research (EER) in its *Annual Decarbonization Perspective 2022* (Haley et al. 2022), which uses the EnergyPATHWAYS demand-side model in combination with the Regional Investment and Operations (RIO) model. Health benefits were calculated using the CO–Benefits Risk Assessment (COBRA) model of the US Environmental Protection Agency (EPA), which contains both a reduced-form air quality model as well as a health impacts model (EPA 2024). This technical appendix provides the assumptions needed to build on these two previous analyses, though for a more detailed description of the work of UCS and EER, see Clemmer et al. 2023 and Haley et al. 2022.

Modeling Framework

ACEA focuses on four scenarios: Reference without IRA/IIJA, Reference with IRA/IIJA, Net Zero, and Net Zero/Low Demand. ACEA's Table A-1 outlines a fuller range of the scenarios considered. *Freedom to Move* focuses on the differences between decarbonized futures with different levels of car dependence and transportation options (i.e., VMT). The key scenario differences are outlined in Table A-1.

However, the ACEA's Net Zero/Low Demand and Net Zero/Ambitious Demand Reduction scenarios contain demand reductions in all sectors, including buildings and industry. For transportation, they include demand reductions in passenger mobility and freight, aviation,

Table A-1. Scenarios for Emissions Reduction Trajectories in the US Energy System under Various VMT Assumptions

	Net Zero (2050)	Net Zero/Low VMT Reduction (2050)	Net Zero/High VMT Reduction (2050)
Light-Duty VMT	— +21% total from 2023 +8% per capita from 2023	-20% from 2050 Net Zero -3% total from 2023 -13% per capita from 2023	-40% from 2050 Net Zero -27% total from 2023 -35% per capita from 2023
Light-Duty Vehicle Sales	+9% from 2023	-3% from 2023	-15% from 2023
Transit and Intercity Bus VMT and Passenger Rail PMT*	— +19% bus VMT from 2023 -27% passenger rail PMT from 2023	+50% from 2050 Net Zero +78% bus VMT from 2023 +9% passenger rail PMT from 2023	+100% from 2050 Net Zero +137% bus VMT from 2023 +45% passenger rail PMT from 2023

*Passenger miles traveled

and shipping. In *Freedom to Move*, we consider only the impacts of demand reductions in passenger mobility, given that freight and aviation changes require a largely separate set of policies. We isolate changes in these lower-demand scenarios in the following EnergyPATHWAYS subsectors: light-duty autos, light-duty trucks, buses, and passenger rail. Demand for these subsectors are expressed as vehicle miles traveled (VMT) or passenger miles traveled (PMT) and follow the assumptions made to generate the data in Table 1 of the main text. We note these data as the effects of VMT reduction while also noting that we currently focus only on passenger mobility. As a result, we pull specific numbers that show the benefits of more transportation options and associated reductions in VMT. Table A-2 summarizes how each individual benefit was derived.

Results for supply-side effects (e.g., electricity-generating capacity, grid energy storage, electricity transmission, energy system capital investments) require the assumption that load reductions from all sectors (e.g., buildings and industry energy-demand reductions) result in similar changes to the grid. RIO models capacity at a more granular level, considering load flexibility and underlying load curves of different demand technologies, and in the Net Zero scenario, contains assumptions of electric vehicle (EV) rate structures that better support a highly renewable energy system. Potential future work could entail rerunning EnergyPATHWAYS and RIO models with updated, isolated assumptions.

Lithium Demand for Electric Vehicles

VMT reduction assumptions for light-duty autos, light-duty trucks, and bus subsectors are translated to reduced vehicle stock by using Center for Neighborhood Technology's Housing and Transit (H+T) Affordability Index data (CNT 2024) at the block-group level. CNT numbers for a national typical household control for the effects of income, household size, and commuters per household, isolating the relationship between VMT and vehicle ownership attributed to transportation system and land-use changes.

We then used a population-weighted regression model, regressing changes in vehicle ownership per capita on light-duty vehicle ownership per capita between 2016 and 2019. This captures the potential of VMT changes to affect vehicle ownership on the margin rather than on average, which matches the potential for policies to change VMT and vehicle ownership in the scenarios we outline. This yields a **29,412 annual VMT per light-duty vehicle** (the inverse of 3.3999e-05 light-duty stock per VMT, standard error [SE] = 2.0533e-07), which we benchmark to other datasets and specifications using the Federal Highway Administration's (FHWA's) *Highway Statistics* series and the Bureau of Transportation Statistics' (BTS') Local Area Transportation Characteristics for Households survey (LATCH). We assume that these vehicle stock reductions are applied across all vehicle technologies evenly (i.e., VMT reduction policies do not reduce gasoline vehicle ownership more than electric vehicle ownership).

For the increase in EV and plug-in hybrid electric vehicle (PHEV) bus stock, we applied a similar methodology, focusing on fixed-route buses and excluding rail, demand response, vanpool, and trolleybus services. Using American Public Transit Association's *Public Transportation Fact Book*, Tables 8 and 11 (APTA Public Transportation Fact Book 2024), we found an 86.7 percent ratio of vehicle revenue miles (VRM) to VMT for all bus modes across 1995 to 2020. We then applied this factor to FTA's National Transit Database TS4.1 and TS2.1 (NTD 2024), which include bus stock and VRM by transit agency from 1992 to 2022. We used the following model specification:

Table A-2. Key Assumptions for Benefits of Net Zero/Low VMT Reduction and Net Zero/High VMT Reduction Scenarios

Benefit	Assumptions
Electricity-Generating Capacity	Take the percentage of electricity demand reduction contributed by VMT reduction in ACEA's Net Zero/Low Demand and Net Zero/Ambitious Demand Reduction scenarios (23% in each), and scale the electricity-generating capacity reductions from RIO model results of ACEA scenarios by this percentage. Convert to real-world numbers using these factors: • Solar – Average of 1.887 million photovoltaic panels per gigawatt (EERE 2024a) • Wind – Average capacity of 3.2 megawatts (MW) for newly installed US wind turbines in 2022 (EERE 2024b) • Natural gas power plants – Average of 250MW per power plant in 2022 (Yang 2023)
Grid Energy Storage	Use same method as Electricity-Generating Capacity.
Electricity Transmission	Use same method as Electricity-Generating Capacity.
Energy System Capital Investments	Use same method as Electricity-Generating Capacity, but include nonelectricity demand reductions such as fossil fuel production, hydrogen, carbon capture, utilization, and storage, and biofuels. Discount dollar figures at 2% and express in 2024$.
Electricity Demand	Isolate aforementioned VMT reduction subsectors in existing demand-side model results from ACEA's Net Zero/Low Demand and Net Zero/Ambitious Demand Reduction scenarios. Then use electricity price projections for transportation from the EIA's *Annual Energy Outlook 2023* to estimate future cost savings (EIA 2023a, table 3).
Gasoline	Isolate aforementioned VMT reduction subsectors in existing demand-side model results from ACEA's Net Zero/Low Demand and Net Zero/Ambitious Demand Reduction scenarios. Convert to gallons using Btu-gallon equivalent of 25,000 Btu/gallon (BTS 2024 Table 4-6). Then use gasoline price projections from *Annual Energy Outlook 2023* to estimate future cost savings (EIA 2023a, Table 12). To note, gasoline prices are highly volatile and shaped by supply-and-demand side dynamics (Martin 2022), and EIA's Reference case takes a relatively stable, conservative approach. Differences with RMI's Smarter MODES Calculator are attributed to a difference in gasoline price projection (Moravec et al. 2024).
Hydrogen	Isolate aforementioned VMT reduction subsectors in existing demand-side model results from ACEA's Net Zero/Low Demand and Net Zero/Ambitious Demand Reduction scenarios. Convert to kilograms using Department of Energy (DOE) hydrogen energy content estimates of 120 MJ/kg, or around 948 Btu/kg (EERE n.d.). Then use hydrogen price projections from IEA 2019 to estimate future cost savings.

$$agency\ bus\ VMT = \beta(agency\ bus\ stock) + year\ fixed\ effect + agency\ fixed\ effect$$

where β is the effect of VMT per bus, weighted by transit agency bus stock, and resulted in **10,605 VMT per bus** (SE = 189). We used this number, as it reflects a marginal approach for each agency and controls for year-based fixed effects that affect all agencies.

To translate reduced vehicle stock into reduced EV sales, we utilized a stock-turnover model based on Argonne National Laboratory's VISION model (Argonne National Laboratory 2024). We began by using National Energy Modeling System (EIA 2023b) survival rates for different vehicle classes, then optimized a simplified national survival rate for light-duty EVs, light-duty PHEVs, and transit buses that does not vary by year, region, or more detailed vehicle class. We optimized rates to match total subsector stock and sales numbers from ACEA scenarios, which largely derive from the *Annual Energy Outlook,* as an alternative to using VISION's approach of survival rates coupled with large adjustment factors.

These reduced sales numbers are combined with cathode chemistry, battery size, and recycling projections to produce reduced lithium demand. This entire process is outlined in Dunn et al. forthcoming.

Health Impacts Analysis

We ran COBRA using a modified version of the criteria air pollutant scenarios for ACEA's Net Zero/Low Demand and Net Zero/Ambitious Demand Reduction scenarios to compute our analysis' Net Zero/Low VMT Reduction and Net Zero/High VMT Reduction health benefits. This built on existing subsector-attributed criteria air pollutant data from ACEA, which was translated into COBRA emissions reductions scenarios using the original ACEA COBRA input files as well as a valuation file from the EPA, with a few changes.

We isolated changes in only the emissions source tiers of Highway Vehicles (including heavy duty and light duty, and gasoline and diesel fuels) to capture tailpipe and brake- and tire-wear emissions; Fuel Combustion: Electric Utility to capture grid emissions for electric vehicles; Petroleum and Related Industries – Petroleum Refineries and Related Industries for upstream refinery emissions; and Petroleum and Related Industries – Oil and Gas Production for upstream emissions from grid-related fuel production.

Because COBRA is a linear model (i.e., benefits from different source tiers can be isolated and added together later), the final health impacts are sensitive only to the relative change in emissions for different counties for different emissions sources. We excluded all other emissions categories from this analysis.

For Fuel Combustion: Electric Utility (TIER1 = 1), we isolated the criteria air pollutant (NH_3, NO_2, SO_2, primary $PM_{2.5}$, and VOC) emissions attributed to changes in the key VMT reduction subsectors noted above (light-duty autos, light-duty trucks, buses, and passenger rail) by scaling the existing Net Zero scenario dataset by the decrease in total electricity energy demand caused by VMT reduction. EnergyPATHWAYS produced demand-side results for grid regions in ACEA, but we reduced electricity demand proportionally based on EER's original COBRA inputs at the county level used in ACEA.

For Highway Vehicles (TIER1 = 11) , we similarly had to resolve spatial scale but utilized the direct criteria air pollutant data attributed to VMT reduction subsectors. This ACEA air pollutant data contains only tailpipe pollutants from internal combustion engine vehicles. This difference in approach is because EnergyPATHWAYS does not attribute criteria air pollutant emissions of EVs directly to transportation subsectors in its demand-side outputs. Similarly, pollution reductions were scaled using EER's original COBRA inputs at the county level.

To include fine particulate matter pollution from brake- and tire-wear, we utilized emissions factors from MOVES3 from a national-scale run inventory for 2017 (Table A-3). Given the relative lack of research on how EVs change brake- and tire-wear emissions (EVs are usually heavier, which increases tire-wear emissions, but they also use regenerative braking that reduces brake-wear emissions), we applied the same total brake- and tire-wear emissions factor to all vehicles, regardless of fuel type. These emissions factors were applied to the total VMT changes in each subsector in each region and added to the existing ACEA air pollutant file.

Table A-3. MOVES3-Derived Emissions Factors (milligrams per vehicle-mile)

Emissions Category	Light-Duty Passenger Car	Light-Duty Passenger Truck	Transit Bus	Intercity Bus
$PM_{2.5}$ (brake wear)	2.77	2.88	9.45	15.50
$PM_{2.5}$ (tire wear)	1.28	1.28	2.35	3.87
Total	4.05	4.16	11.80	19.37

SOURCE: Office of Transportation and Air Quality 2020, Tables 3-13 and 4-5.

For upstream emissions in Petroleum and Related Industries (TIER1 = 6), we derived emissions factors from Wang et al.'s 2023 Greenhouse Gases, Regulated Emissions, and Energy Use in Technologies Model (GREET) using default values for baseline gasoline, baseline conventional and low-sulfur diesel, and electricity (natural gas power plant), as summarized in Table A-4. We assumed that upstream emissions factors do not change over time from 2022 as a simplifying assumption. We applied gasoline and diesel emissions changes to Petroleum and Related Industries – Petroleum Refineries & Related Industries. For electricity, we used GREET 2023 for only feedstock-related emissions (i.e., we used ACEA numbers for combustion-related emissions) and assumed negligible upstream-related emissions from renewables. We applied these emission factors to national energy demand and applied that proportionally based on existing emissions across the country, given the wide geographic distribution of petroleum refining and fossil fuel upstream activities. Natural gas upstream emissions were applied to Petroleum and Related Industries – Oil & Gas Production – Natural Gas, whereas coal upstream emissions were applied broadly to the Petroleum and Related Industries emissions tier.

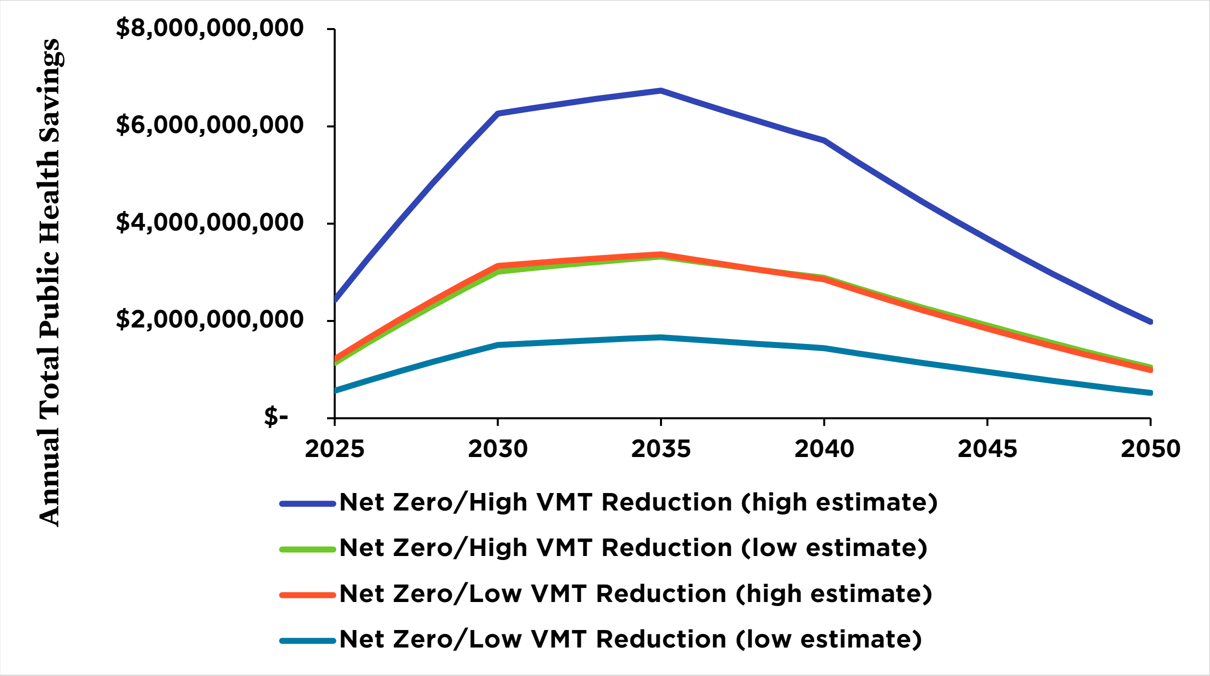
Table A-4. GREET 2023–Derived Upstream Emissions Factors (g/mmBtu)

Criteria Air Pollutant	Upstream Gasoline	Upstream Diesel	Upstream Electricity: Natural Gas	Upstream Electricity: Coal
$PM_{2.5}$	1.888	1.095	0.805	3.637
NO_x	25.831	18.449	67.868	16.657
SO_x	6.916	4.762	24.508	20.670
VOC	29.518	7.479	20.752	22.423

*grams per metric million British thermal units
SOURCE: Wang et al. 2023.

The results of running COBRA utilizing these scenarios for 2025–2050 at five-year time intervals (using a batch script) were then inputted into a specific EPA COBRA output processing tool, which helped with discounting (utilizing a rate of 2 percent) and data aggregation. Full results of the health benefits are shown in Figure A-1.

Figure A-1. Health Benefits Peak in the Near Term Due to Reduced Tailpipe, Brake Wear, Tire Wear, and Upstream Gasoline, Diesel, Natural Gas, and Coal Emissions



SOURCE: UCS analysis using EPA 2024.

It is important to note a few more caveats. COBRA does not include Alaska and Hawaii, but EnergyPATHWAYS does. Including these states would have resulted in even greater health benefits. Also, this analysis does not include emissions from increased passenger rail or upstream emissions avoided from hydrogen that are not already captured in electricity system demand due to the scope of COBRA and their smaller relative contribution. In addition, since *Accelerating Clean Energy Ambition* was published, COBRA was updated to v5.1, which contains the public health impacts of ozone. Last, due to the coarse spatial scale of COBRA, we were not able to conduct a distributional analysis (e.g., by race), though this could be within scope for future work using a combination of other reduced-form air quality models like InMAP and more granular health impact modeling using BenMAP.

Maintenance, Depreciation, and Traffic Fatality and Injury Estimates Using RMI's Smarter MODES Calculator

To apply the RMI Smarter MODES calculator to our analysis, we used the light-duty VMT reduction numbers for internal combustion engine vehicles and EVs (including hydrogen fuel cell vehicles) from the ACEA model. We then applied the calculator's estimates for maintenance costs for both vehicle types and projections for avoided depreciation costs per mile to project total maintenance and depreciation cost savings. All dollar amounts were then converted to 2024 dollars and discounted at 2 percent. Similarly, for traffic fatality and injury estimates, we used the existing factors within the Smarter MODES calculator.

Appendix B: Government Spending Methodology

To assess total government spending on transportation, we used data from a range of sources covering different time periods. Because the different sources of data do not capture identical datasets, overlapping years of coverage were used to best ensure the data was aligned. The data sources we used are described along with any limitations on the datasets. These data were then converted to constant dollars.

Sources of Transportation Spending

Census of Governments

The US Census Bureau annually collects financial data from state and local governments as authorized by Title 13, US Code, Section 161 for census years and Section 182 for noncensus years. For years ending in 2 and 7, a full census of all states is conducted, while in the intervening years a sample of state and local data is selected. A new sample is selected every five years (those ending in 4 and 9).

These data have been collected annually since 1957 under the Census of Governments Act of 1950. Prior to 1957, annual reporting was available for state financial data in all years since 1915, except 1920, 1921 (partial), and 1933 through 1936 (inclusive). Historical data are available from the Census Bureau dating back to 1900, though transportation-relevant expenses are omitted prior to 1915 (US Census Bureau 2010). State-specific data are also available in a series of regular annual reports (US Census Bureau 1916-1993).

These data were used to determine all Utah transportation spending through 1956, Utah transit expenditures for 1957 through 1991, and Utah operations and maintenance expenditures on highways for 1957 through 1990. They were also used to determine state and local transit spending through 1974 and state and local capital expenditures on transit from 1975 through 1981.

Department of Transportation

Highway Statistics

The Federal Highway Administration (FHWA), and the Bureau of Public Roads before it, has regularly published data on highways, including federal, state, and local expenditures. Historical data are available digitally through 1995 (FHWA 1996-2023), both at the aggregate level, and, on a limited basis, at the state level (Teets 1997). The FHWA has historically released summary reports, most recently through 1995. These data were also published as part of its *Highway Statistics* report series, published annually (FHWA 1996-2023). Prior to 1957, the state highway spending tabulated was exclusive to spending on state-controlled roads. Additionally, the state-level historical data highlighted only maintenance costs rather than all associated operations and maintenance costs, underestimating the total noncapital expenditures.

We used highway finance data from Table HF-210 for highway expenditures at the federal level and for local and state expenditures aggregated nationally. State-level data are available in Table SF-2. Local-level data are available in Table LGF-2.

We used this dataset to determine national aggregate highway spending over the entire time period. We also obtained data on Utah's highway capital spending from 1957 onward and Utah's highway operations and maintenance spending from 1991 onward.

Bureau of Transportation Statistics

Formally authorized in the Intermodal Surface Transportation Efficiency Act (ISTEA), the Bureau of Transportation Statistics (BTS) was established to set key transportation metrics and create monitoring tools as well as compile and integrate transportation data that had previously been distributed through the agency's various offices. One regular annual report produced by BTS covers the financial statistics for local, state, and federal government (Sen, Eversole, and Church 1997). This dataset maintains aggregated information on capital and operating expenditures for transportation.

This dataset was used for local, state, and federal transit spending for 1982 through 1991.

National Transit Database

Formally established in 1995, the Federal Transit Administration's (FTA's) National Transit Database (NTD) built on the requirements of the Federal Transit Act to maintain a central government source of information on transit systems around the country, including on funding. Data are available through the NTD for approximately 850 different transit providers. Time series data are available on funding and expenditures (NTD 2024, TS1.2 - Operating and Capital Funding Time Series).

Because this is the most comprehensive data source on transit, we used these data forward from 1992, which is as far back as is accessible. These data were used for transit costs at all levels, including for Utah specifically.

American Public Transit Association

The American Public Transit Association published its first fact book in 1943, and the now-annual report represents a compendium primarily consisting of data found in the FTA NTD (APTA Public Transportation Fact Book 2024). However, we used its historical data, which go back further than the NTD, to patch a gap in data for state and local operations and maintenance data from 1975 through 1981, where there seemed to be substantial disagreement between the Census of Government data and the BTS data. Because these data are nationally aggregated, they were not used for the state of Utah.

Federal Budget Data

The Congressional Budget Office (CBO) periodically provides information on spending by federal, state, and local governments for transportation and water infrastructure, most recently in 2018 (Musick 2018). The federal data in this report come from the Office of Management and the Census Bureau and date back to 1956. We were able to obtain budget data back to 1940 and to largely reproduce the values in the CBO report, but there is only a low level of detail. Further, we were able to reproduce these data through a BTS report (Rossetti et al. 1997) and used the CBO data to account for federal transit spending through 1991.

The methodology considered for capturing inflation in the CBO analysis was also replicated (see next section).

Accounting for Inflation

Because the cost of structures and goods are not constant over time, it is important to account for inflation when considering the historical record. To do this, we applied the same method as that for the CBO report, which uses price indices for government expenditures on structures and consumption as inflationary measures for capital outlays and operations and maintenance, respectively (Musick 2018, p. 21, footnotes a and b). These data are available for federal (nondefense) and state/local government expenditures (BEA, 2024g). All values were calculated relative to 2024$, for which we normalized to the 2024Q2 indices.

The BEA data date back only to 1929. For prior to 1929, we used the consumer price index to account for inflation between the given year and 1929 (US Bureau of Labor Statistics n.d.) and then used the BEA data to account for the remaining inflation. While government is not the average consumer, this represents a standard measure of inflation and one that has been calculated prior to 1929. Moreover, because government investment in transportation has increased substantially since this time period, any errors introduced through this accounting of inflation do not affect any overall conclusions reached with the data, since these data represent only a small share of total expenditures over the past century.

Appendix C: Transportation Funding Flow Diagram Methodology

In considering the total cost of transportation funding, it is important not only to focus on contributions to the Highway Trust Fund or on how much governments spend on roads and transit but to look at the actual dollars input into the system by both government and users of the transportation system. By allocating these dollars into flows via a Sankey diagram, we illustrated the major sources of transportation dollars and where those dollars ultimately end up.

Government Revenue and Spending and Fiscal Year 2021

For decades, the Office of Highway Policy Information within the FHWA has produced an annual report highlighting critical statistics about highways, including revenue and expenditures (FHWA 1996 -2023). Unfortunately, information on local government expenditures is not available on an annual basis because local government reporting is done biennially, with even-numbered years optional. The most recent publication of the annual Highway Statistics data is for fiscal year 2022, which means that the most current and comprehensive local spending information goes through fiscal year 2021 (FY2021). The tables used from this data source, along with a description and application of the data, are identified in Table A-5.

Because the FHWA is the most reliable source of information, we used FY2021 as the year of study because of this limitation. The COVID-19 pandemic affected travel in this time period, which may lead to some anomalous characteristics in the data; however, private vehicle travel patterns returned to normal halfway through FY2021 (BTS 2023, Figure 2-2), and much of the cost of our transportation system (insurance, licensing, vehicle ownership) is independent of use. Transit ridership, however, has not returned to prepandemic levels, and Congress did pass substantial COVID-19–related funding support for both highway and transit funding in FY2021 that is reflective of government's frequent funding for transportation from general funds but that may not be representative of the level of federal government funding on an annual basis.

Because of the way transportation funding works, money collected in one year is not necessarily distributed in that same year. Because we looked at flows rather than overall account balances, we tracked solely the disparity between inflows and outflows, allocating such net increases as specific outputs where appropriate (notably for the Highway Trust Fund and state balance sheets). However, these values are relatively small in terms of overall funding.

In some cases, different government agencies may have different values for the same allocation. For example, although FHWA tracks the dispensation of state registration fees for transit (FHWA 1996-2023, Table MV-3), FTA also tracks these data as part of its National

Table A-5. Highway Statistics Data Tables, Descriptions, and Relevant Information Collected

Table Number	Title	Data Description
FE-1	Status of the Highway Trust Fund	Monthly data on trust fund income, expenditures, and transfers
FE-210	Status of the Highway Trust Fund	Annual specificity on source of income (e.g., motor fuel taxes, excise taxes, etc.)
FA-5	Receipts and expenditures for highways by federal agencies	Taxes, general appropriation, and other federal receipts; transfers to state and local governments; outlay amount and description
HF-10	Funding for highways and disposition of highway-user revenues, all units of government	Summary of other tables and includes additional detail on bonds, interest, finances
SDF	Disposition of receipts from state and highway-user imposts, including tolls	Summary of state revenues and disposition
SF-1	Revenues used by states for highways	Detailed description of revenues used for highways by states
SF-2	State disbursements for highways	Detailed description of disbursements for highways by states
SF-6	State expenditures and grants-in-aid for local roads and streets	More detail on state disbursements for local roads
SB-3	State obligations for highways, receipts and disbursements for debt service	Detail on bond finance and investment revenue for states
LDF	Disposition of local government receipts from state and local highway-user revenues	Summary of revenues transferred to or assessed by local governments and their disposition
LGF-1	Revenues used by local government for highways	Detailed description of revenues used for highways by local governments
LGB-2	Local government obligations for highways, change in indebtedness during year	Detail on bond finance and investment revenue for local governments

Transit Database (NTD 2024, Funding Sources). Where there is disagreement between agency data, we have generally relied upon the agency responsible for administering the revenue in question (i.e., FHWA for highway data, FTA for transit data). It is worth noting that such disparity was generally much less than 1 percent of any value.

Other Government Data Sources

While many data sources are directly related to revenue or expenditures from government agencies, not all expenditures are captured in these datasets. However, to the degree that we could continue to rely on government-produced estimates of any data, we did.

Fuel Data

The Energy Information Administration (EIA) within the Department of Energy monitors a range of data on petroleum products and other fossil fuels. As part of its regular update on pricing information, the agency estimates the share of gasoline and diesel price that covers taxes, distribution and marketing, refining, and the cost of the crude oil itself (EIA n.d.-a). By combining this information with the data on petroleum product volumes (EIA n.d.-b), it is possible to estimate the share of fuel costs spent on crude oil, distribution and marketing, and refining (motor fuel taxes are already tabulated by government sources in a previous section). Because these data are available on a weekly basis, we can calculate fuel costs directly for FY2021 (October 1, 2020, through September 30, 2021).

Economic Data

The Federal Reserve houses a number of government-collected economic datasets under the Federal Reserve Economic Data (FRED), maintained by the Federal Reserve Bank of St. Louis. We used these data to help assign and assess costs related to insurance, fuel, vehicle purchases, and vehicle maintenance and repair.

Many of these datasets are collected annually, which means they do not align with the fiscal year. To estimate the fiscal year dataset, we first applied an inflation factor to convert the 2020 values into 2021$, and then we did a weighted average of 3:1 for 2021:2020 costs, representing the 3:1 quarter breakdown for the fiscal year. While this is a simplistic approximation, the result led to only modest reductions comparing the calendar year 2021 data and those of FY2021, which is consistent with the impact of the COVID-19 pandemic and recovery.

Insurance

Insurance for privately owned vehicles is collected as part of the Bureau of Economic Analysis calculation of gross domestic product (BEA 2024e). This reflects the net cost to households (i.e., includes disbursements for damages) rather than the absolute cost paid for insurance (a relevant point when considering interaction with costs related to vehicle damage, since these are paid for through insurance premiums).

Insurance for commercial vehicles is collected as part of the Service Annual Survey of the US Census Bureau (2024a). Because these values consider only for-hire trucking firms, the values were then scaled by vehicle miles traveled for all heavy-duty trucks to reflect the total cost of insurance.

Fuel

As noted above, the total fuel costs were obtained from EIA data. While most commercial freight carriers use diesel fuel, a nontrivial amount of commercial heavy-duty traffic is powered by gasoline. To assess what share of fuel is associated with private versus commercial usage, we relied upon household expenditures on gasoline (BEA 2024c).

Vehicle Purchases

The BEA tracks both new and used vehicle purchase data (BEA 2024f; BEA 2024b). However, these data do not fully capture the value of the car market because they overlook car dealerships.

A person calculating the value of new cars sold would find that there is a large gap between the average transaction price according to industry reports and the average transaction price according to BEA data. This gap is largely related to trade-in value. A car is purchased from a vehicle manufacturer by a dealer. A new car buyer will typically trade in a used vehicle, which the car dealer will usually mark up and sell, and the purchaser will pay or finance the balance of the vehicle cost. According to BEA data, this is tabulated as the new vehicle data. Only the markup on the vehicle counts toward the net used vehicle purchase because the new car buyer receives the trade-in value. Because this leaves a substantial unvalued gap and does not fully reflect the annual costs paid by consumers, we have used only the BEA data to aid attribution of costs to new and used vehicles and as a check against the data from automotive dealers, which act as the primary source.

Vehicle Maintenance and Repair

Another household vehicle expenditure is maintenance, repair, and parts, all of which are tabulated by the BEA (2024a; 2024d). Similarly, the US Census Bureau (2024b) tracks such data for commercial trucks. However, in none of these cases is information available on labor versus part costs or profit margin to allocate these costs appropriately—for that, we turned to nongovernmental sources of data.

Nongovernmental Data Sources

As noted previously, there are gaps in government data, particularly when it comes to allocating costs related to the vehicle industry. To better understand the costs and distribution of costs related to transportation, we used industry data sources.

Automobile and Truck Dealers

The National Automobile Dealers Association (NADA) produces an annual summary of its members (NADA 2020; NADA 2021). This document breaks down financial data on vehicle sales by dealers between new and used and provides data on labor, parts, and profit margin for the service and parts divisions of its members. Within the parts program, it also identifies costs associated with warranty repairs, which are covered by the vehicle manufacturers.

The American Truck Dealers (ATD) is a division of NADA focused on new heavy-duty truck dealerships. It regularly publishes its own financial reports detailing similar data to NADA (ATD 2021; ATD 2023). These data can be used to allocate relevant repair costs.

Trucking Industry Research

Another source of information on the trucking industry is the American Transportation Research Institute, a nonprofit research entity controlled by the American Trucking Associations. This research organization produces regular reports on the industry overall as well as specialized reports focused on issues of concern to the trucking industry. A report on tolling was used to assess what share of tolls are paid by the trucking industry (Short and Peters 2020).

Appendix D: Grassroots Partner Features

UCS provides many resources for scientist-community partnerships, of which one promising route is community-based participatory research (UCS 2024). Communities have deep expertise from firsthand experience with the issues that many technical experts may miss. Together though, there is the potential for real change. In this report, we partnered with three grassroots organizations to ground our work in community experience while also uplifting and creating materials that are of use to our partners.

One key part of this structure is to set explicit expectations for the relationship and protect against extractive practices. For this, in addition to more informal conversations, we used a memorandum of understanding largely based on work done by the West End Revitalization Association with the Environmental Justice Practitioners' Working Group at Association for Advancing Participatory Sciences (Wilson and Wilson 2020, available upon request), which recommends both a document outlining an understanding of shared values as well as an explicit document outlining expectations and scope of a project, mutual interest, funding equity, management parity, legal leverage, authorship, and public presentation of the work. Additionally, we compensated our grassroots partners for their time working on this project. Making these expectations explicit is crucial for addressing a long history of exploitative or disconnected research related to impacts on the ground.

Collaborating with grassroots partners not only helps highlight the real-world examples of injustice—distributive (e.g., affordability and disinvestment in communities such as Roxbury, or for nondrivers in rural Utah, or in historically Black neighborhoods like Allendale), deliberative (e.g., exclusion of ACE or Allendale Strong from transit or highway planning decisionmaking processes), procedural (e.g., the need for the T Riders Union), and restorative (e.g., long histories of disinvestment experienced by all three partners)—but also acts to address epistemic injustice, where community groups are often not valued on par with other forms of knowledge that UCS is more associated with (see Figure 8, main text). In the end, collaboration with grassroots groups was key to centering the lived experience of marginalized communities and conducting science for a more sustainable and just future.

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