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Financial Impacts of Road User Charges on Urban and Rural Households

Prepared for:
Western Road User Charge Consortium (RUC West)

In cooperation with
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INTRODUCTION

This report provides a discussion, documentation and references to the sources of data used to develop an analysis of the financial impacts of a revenue-neutral road user charge (RUC) for drivers in urban and rural counties for eight states in the Western Road Usage Charge Consortium (WRUCC). The analysis conducted for this study was applied uniformly to all eight participating states so that a clearer and more comprehensive assessment of the impact of RUCs could be developed, and so that any differences in financial impact on a state-by-state basis could be understood in the context of a consistent methodological approach.

Initial criteria for categorizing counties into those with either urban or rural characteristics were developed as part of a separate memorandum to the WRUCC's Project Advisory Committee (PAC). In that memorandum, the study team recommended that subsequent analysis be focused at the census tract level and that census tracts be designated as urban, rural or mixed to fully reflect the variation in travel characteristics for some of the larger, more diverse counties that characterize the member states. This recommendation was accepted, and all subsequent analysis was conducted using census tract-based information. Final tabulations in this report are provided on a state-wide basis with detailed information displayed at the census tract level.

The report is organized so that the chapters correspond to each of the key tasks required for the study. Chapter 1 presents the estimates of annual vehicle miles traveled (VMT) by non-gasoline powered vehicles (Task 3), Chapter 2 identifies the costs borne by each urban, mixed and rural census tract in each of the states (Task 4), and Chapter 3 provides an estimate of the financial impacts to households in urban, rural and mixed census tracts in each of the states (Task 5). Chapter 4 documents the methods used for the study and how they were incorporated in the tool (Tasks 6 and 8).

Key Assumptions of this Analysis

- Financial impacts are measured at the place of household residences, which are categories as urban, mixed and rural at a census tract level of geography
- State vehicle registration data is a key component of this analysis
- Other data sources are from national, publicly-available sources to allow consistency across all eight states and reproducibility.
- All relevant vehicles are registered at the place of household residence
- Only on-commercial household vehicles are included, with diesel and non-gasoline fossil fuels excluded.
- RUC rate tested is revenue neutral on a statewide basis for studied population

There are five appendices included with this report. Appendix A documents the urban-rural classification scheme developed for Task 2, via the memo delivered during that stage of the project. Appendix B shows census tract detail on a state-by-state basis showing the percent of census tract VMT by state for each fuel type assessed in the study. Appendix C shows the percentage increase or decrease in costs under a revenue neutral RUC by census tract for each of the participating states. Appendix D discusses details of the vehicle registration decoding, while Appendix E provides the VBA code used by the tool delivered.

Data on vehicle registration information used in this report was provided with the cooperation of the participating states. A computer-based system to replicate this analysis is being provided as a separate work product so that other members of the WRUCC can replicate the analysis. The study team sincerely appreciates the cooperation and feedback from each of the participating states in developing the data used in this report.

Chapter 1: Estimates of Annual VMT by Non-gasoline-powered Vehicles (Task 3)

This section of the report describes the basis for estimates of the annual vehicle miles traveled (VMT) by non-gasoline powered and hybrid passenger vehicles for each of the states that provided data for this study. An estimate of annual non-gasoline-powered vehicle miles traveled (VMT) for each state is necessary to calculate accurate per-vehicle expenditures based on the current gas tax and a Road User Charge (RUC) alternative. This is important as some vehicles are currently paying little or no gas tax (depending on the type of vehicle) and will begin to pay a full share of costs currently covered by the gas tax under a RUC, while other vehicles (e.g., diesel-powered vehicles) will continue to pay a different type of tax. EDR Group has developed estimates of VMT for gas and non-gas powered vehicles as shown in Table 1. Appendix B shows the distribution of VMT associated with different fuel types across the participating states, with separate maps for the initial seven states completed and for Texas.

Non-gasoline-powered VMT is estimated by combining two lines of analysis. First, VMT is estimated for each census tract in the participating states using household characteristics. Second, fuel type mixes are estimated at the lowest geographic level possible with the vehicle registration data provided by the states. These estimates are combined to estimate fuel type shares of VMT in each tract. Vehicle use is assumed to be independent of vehicle fuel type, such that a gasoline-powered car and an electric car travel the same mileage per year. The following sections explain the estimation methodology and are designed to be used to produce a similar analysis for non-participating states. Table 1 shows the total estimated VMT in each participating state, the total estimated non-gasoline VMT, and the share of total VMTs attributable to non-gasoline powered vehicles.

Table 1. Estimates of Total Annual VMT, Non-Gas VMT, and Non-Gas Percent of VMT for the Participating States

State	Total VMT (Billions)	Non-Gasoline VMT (Billions)	Non-Gasoline Percent of Total
Arizona	26,771	2,657	9.9%
California	155,826	7,542	4.8%
Idaho	7,800	643	8.2%
Montana	5,152	1,046	20.3%
Oregon	17,329	2,262	13.1%
Texas	130,396	24,841	19.1%
Utah	12,633	1,877	14.9%
Washington	32,205	2,476	7.7%

Montana and Texas show the highest non-gasoline-powered share of VMT in Table 1. Oregon and Utah also show considerable penetration of other fuel technology. Table 2 and Table 3 provide VMT counts and percentages, respectively, that are attributable to electric, hybrid, flex fuel and biofuel[1], diesel, and alternative fossil fuels categories of non-gasoline-powered VMT. This information helps understand the nuances driving the results in Table 1. High shares of non-gasoline powered VMT in Montana are largely driven by a much higher percent of diesel in the registration data. Texas has by far the highest flex/biofuel

[1] Flex fuel and biofuel vehicles are those which can operate some of the time or all of the time using biofuel mixes that are unsuitable for standard vehicles. A significant portion of gasoline sold in the United States contains up to 10 percent ethanol and most gasoline combustion engines can safely operate with up to 15 percent ethanol content.

and other fossil fuel penetrations. Oregon has the highest penetration of hybrid vehicles. Oregon and Utah also have higher than average diesel-powered VMT.

Table 2. Annual VMT by Type of Non-Gasoline Fuel for the Participating States (in Millions)

State	Electric/ Hydrogen	Hybrid	Flex fuel/ Biofuel	Other Fossil	Diesel	Total Non-Gas
Arizona	20.3	514.0	1,794.9	3.9	323.7	2,656.7
California	605.5	3,216.4	1,937.1	117.2	1,665.9	7,542.0
Idaho	1.1	67.4	395.3	0.7	178.3	642.9
Montana	0.0	63.5	275.9	0.8	695.0	1,035.1
Oregon	0.1	489.2	778.6	1.1	992.7	2,261.7
Texas	197.5	287.1	17,038.0	3,250.2	4,068.0	24,840.9
Utah	9.9	211.3	918.4	17.4	719.9	1,876.9
Washington	40.6	735.2	1,027.3	1.2	671.5	2,475.8

Table 3. Percent VMT by Type of Non-Gasoline Fuel for the Participating States

State	Electric/ Hydrogen	Hybrid	Flex fuel/ Biofuel	Other Fossil	Diesel	Total Non-Gas
Arizona	0.08%	1.92%	6.70%	0.01%	1.21%	9.92%
California	0.39%	2.06%	1.24%	0.08%	1.07%	4.84%
Idaho	0.01%	0.86%	5.07%	0.01%	2.29%	8.24%
Montana	0.00%	1.23%	5.35%	0.02%	13.49%	20.09%
Oregon	0.00%	2.82%	4.49%	0.01%	5.73%	13.05%
Texas	0.15%	0.22%	13.07%	2.49%	3.12%	19.05%
Utah	0.08%	1.67%	7.27%	0.14%	5.70%	14.86%
Washington	0.13%	2.28%	3.19%	0.00%	2.09%	7.69%

VMT ESTIMATES

To estimate VMT, we utilize regression equations developed for the Bureau of Transportation Statistics' (BTS) 2009 National Household Transportation Survey (NHTS) Transferability Statistics report. These equations are applied at the census tract level using data from the 2009-2013 American Community Survey (ACS).[2] This approach provides the basis for estimating travel characteristics in census tracts with few or no NHTS samples (in some cases, whole counties lack any observations). The BTS equations use the following socio-economic characteristics at the census tract level for VMT estimation:

- Average Household Income
- Average Number of Household Vehicles
- Average Number of Household Members
- Average Number of Workers
- Percent of Households who are Homeowners
- Percent of Households with Children
- Percent of Single Member Households

[2] For more detail, see "Local Area Transportation Characteristics for Households" under the "Detailed Data heading at the BTS NHTS landing page: http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/subject_areas/national_household_travel_survey/index.html

- Percent of Multiple Member Households, No Members Over 65
- Percent of Multiple Member Households, at least One Member Over 65

BTS estimated equations for six regional groupings of states[3], which are further divided into urban, suburban, and rural areas.[4] We utilize the Pacific and Mountain region equations.[5] Urban, suburban, and rural designations are based on an Urbanicity Index, which is calculated based on census tract location within Census-Bureau-designated urban areas and tract population density.[6] Using the Transferability Statistics regressions, we estimate the household (non-commercial light-duty vehicle) daily VMT presented in Table 4. The Transferability Statistics reports estimate weekday VMT. To annualize this daily VMT value we use a factor of 294.1 based on analysis of weekend versus weekday travel in the NHTS.

Table 4. Daily Household Vehicle Miles Traveled Estimates for the Participating States

State	Daily HH VMT
Arizona	91,022,898
California	529,820,872
Colorado	85,835,723
Idaho	26,520,657
Montana	17,516,539
Oregon	58,921,026
Texas	443,356,784
Utah	42,952,381
Washington	109,500,321

While these estimates are based on the most recent ACS data available at the time of the analysis (2009-2013), they cannot capture any change in travel patterns since the 2009 NHTS. Using state-wide travel surveys, with much higher sample rates across geographies, it might be possible to estimate equations that better consider unique characteristics within states. U.S. DOT has just issued surveys for the 2016 NHTS, which will be available in several years. When these results become available, there may be some new information reflecting more contemporary travel patterns.

COMPARISONS TO OTHER DATA SOURCES

We compared the results derived from the BTS estimates for California to other data sources provided by California. Table 5 provides three different values of daily VMT (DVMT) that were considered. The

3 The groupings are based on Census Divisions, and this was the level of geographic resolution that BTS thought was appropriate considering the sample size within each state and the distribution of oversampled regions in the NHTS survey.

4 Urban, suburban, and rural designations do not correspond with the Urban-Mixed-Rural (UMR) designations that we have proposed for carrying out financial analysis, which are based on travel patterns. The urban, suburban, and rural designations are used for calculating VMT in order to be consistent with the BTS methodology, but will not be used elsewhere in the analysis or reporting. We believe proposed travel-based UMR designations will serve as a better reporting tool for the information of interest to this project.

5 California, Oregon and Washington fall in the Pacific Census Region. Arizona, Colorado, Idaho, Montana, and Utah belong to the Mountain Census Region.

6 The census-tract-level Urbanicity Index was developed by BTS for the Transferability Statistics report, and roughly approximates the Census-block-group-level Claritas variables from the NHTS. To by classifies as urban or suburban, census tracts must have at least 30 percent of their population within census blocks inside an urban area boundary. Less dense tracts are classified as suburban (NOTE _ Should this be rural?).

California Household Travel Surveys (CHTS) only captures vehicles owned by households or rental vehicles. The EMFAC[7] figure for passenger vehicles includes additional vehicles such as taxis and for-hire vehicles, as well as additional light truck uses. From Table 5, we can see that the regression estimations provide reasonably consistent levels statewide and appear to be of the magnitude that should be expected, given the types of vehicles included in the CHTS and the EMFAC.

Table 5. Comparison of Statewide Total Daily Vehicle Miles Traveled for California Using Different Data Sources

	CA Household Travel Survey (CHTS)	Regression Estimation	EMFAC Passenger Vehicles
	2012	2009/2013[8]	2012
Total DVMT	478,226,357	529,820,872	640,235,493

We also compared CHTS and the regression estimates on a county-by-county basis and find that for 47 percent of counties, the estimates based on NHTS-derived regression equations are within 10 percent of the CHTS values.

We also compared the regression estimates with facility-based estimates that Montana provided for each county using AADT estimates and network miles. The Montana data showed 20,080,00 miles of light vehicle travel compared to the household estimates of 17,517,000 miles per day. Because Montana's network carries a significant amount of pass-through and tourist travel, this difference is expected. On a county-by-county basis the differences between regression estimates and Montana data are greater than the regressions computed for California, and show a greater variation that comparable estimates developed in relationship to the CHTS. This is also expected because the Montana data measure where travel occurs, while the BTS regression estimates attribute travel to the place of residence of the driver. The counties with the greatest differences are those counties where we would expect these two measures to differ.

The Washington State Transportation Commission's *Road Usage Charge Assessment,*[9] produced a DVMT estimate of 124,500,000 compared to a regression estimate of 109,500,000, normalizing the county-by-county results to matching statewide totals, the regression estimates fall within 10 percent for 49 percent of counties and all counties are within 25 percent.

Based on analysis of the Oregon Household Activity Survey (OHAS) by the survey team, by EDR Group, and by McMullen, et al., in the recently released *Road Usage Charge Economic Analysis,*[10] our regression estimates seem to closely match OHAS for more urban areas, but to underestimate travel for rural households. The most complete solution for this issue would be to develop Oregon-specific, census-tract-level regression equations based on OHAS to replace the BTS-derived equations for the Pacific Census Region.

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7 EMFAC is the EMission FACtors model of the CA Air Resources Board, used to calculate transportation-related air pollution emissions.

8 VMT generation estimated based on 2009 travel patterns in the NHTS and 2013 socioeconomic/demographic information in the 2009-2013 ACS, which includes income and population growth.

9 Washington State Transportation Commission, Road Usage Charge Assessment: Financial and Equity Implications for Urban and Rural Drivers, January 2015. https://waroadusagecharge.files.wordpress.com/2014/05/2015-0227_urbanruralreport.pdf

10 McMullen, B. S., H. Wang, Y. Ke, R. Vogt, and S. Dong, Road Usage Charge Economic Analysis, Final Report – SPR 774, Corvallis, OR: Oregon State University, April 2016. https://www.oregon.gov/ODOT/TD/TP_RES/docs/Reports/2016/SPR774_RoadUsageCharge_Final.pdf

We have not received data from other participating states that would allow a sub-state comparison or even statewide light vehicle comparison of agency data and the regression estimates.

FUEL MIX ANALYSIS

The distribution of non-gasoline vehicles is determined based on the vehicle registration information provided by each state. When states provided a fuel type data attribute, this was used to supplement data decoded from registration records. Most states provided vehicle identification number (VIN) information, which was decoded using the National Highway Traffic Safety Administration's (NHTSA) Product Information Catalog and Vehicle Listing (vPIC) Application Programming Interface (API).[11] The vPIC API provides tools for batch decoding full or partial VINs for a variety vehicle types. Our analysis focused only on light duty cars and trucks identified in the state-provided data. Table 6 provides an overview of the quantity of data received and used in this analysis. The number of attributes, level of pre-processing, and general data quality varied from state to state, which resulted in disqualification of records at different points in the data cleaning process for different states.

Table 6. Universe of Registration Records Used in Fuel Mix Analysis and Four Causes for Difference between Vehicle Records Received and Vehicles Contained in Final Analysis Dataset

State	Registration Records Received	Removed from Analysis because			Location Rebalance[12]	Final Vehicle Count by State
		Not Standard Passenger Vehicles[13]	No Fuel Type ID'd[14]	No Fuel Economy ID'd[15]		
Arizona	5,917,640	8%	1%	10%	2%	4,618,996
California	27,559,122	17%	3%	0%	1%	21,588,525
Idaho	2,746,499	13%	0%	3%	4%	2,194,713
Montana	700,000	10%	1%	8%	5%	528,872
Oregon	3,782,748	0%	0%	33%	0%	2,524,951
Texas	24,203,117	15%	0%	6%	4%	18,047,380
Utah	2,330,852	6%	1%	7%	1%	1,979,521
Washington	5,130,387	1%	0%	15%	0%	4,315,254

The processed registration data was then summarized for different fuel types in each state as presented in Table 7. This table provides insight into the differences in vehicle fuel types that appear in the final dataset and is a major driver of the results presented in Table 2. Table 8 also provides the associated count of vehicle registrations for each fuel type by state.

[11] The vPIC platform includes several tools located at http://vpic.nhtsa.dot.gov/.

[12] States lose vehicles that 1) had registration addresses in one of the 43 states or DC not included in these stages of this project, 2) were registered in census tracts with no households, or 3) were registered in zip codes with no spatial correspondence.

[13] Registration databases included vehicle types such as mopeds, motorcycles, heavy trucks, trailers, motor homes and other vehicles that were excluded from this analysis. The emphasis was on household passenger vehicles that were feasible to match with NHTS and EPA datasets.

[14] Most failures to identify fuel types are due to VIN records that were not decodable using vPIC either due to poor data quality or other unidentifiable reasons.

[15] Major reasons for failure to decode fuel economy are 1) vehicles are too old for fuel economy records, 2) vehicles are too unusual to be contained in EPA's fueleconomy.gov database, or 3) make, model and year are not decodable from VIN or provided by state, but fuel type is provided, so the previous step does not disqualify the record.

Vehicle registrations and their fuel type were identified using the lowest geographic level possible given the state provided data. For some records, geolocation coordinates were available from the state, in other cases, addresses or zip code extensions were used to point-code records. Finally, some data was only available at the zip code and/or county level. Zip-code data was down-allocated to tracts based on Census Bureau crosswalk tables for the number of households in tract-zip intersection regions. If records were not successfully located at one level of resolution, we next attempted to locate them at the next spatially larger level of geography.

Table 7. Percent of Vehicles by Fuel Type for the Participating States

State	Gas Vehicles	Electric/ Hydrogen	Hybrid	Flex fuel/ Biofuel	Other Fossil	Diesel
Arizona	89.53%	0.07%	1.84%	7.36%	0.01%	1.19%
California	95.25%	0.39%	2.01%	1.24%	0.08%	1.04%
Idaho	92.08%	0.01%	0.82%	4.84%	0.01%	2.24%
Montana	79.60%	0.00%	1.21%	5.45%	0.02%	13.73%
Oregon	87.56%	0.00%	2.47%	4.45%	0.01%	5.52%
Texas	80.87%	0.15%	0.21%	13.13%	2.52%	3.11%
Utah	85.06%	0.08%	1.66%	7.32%	0.14%	5.76%
Washington	92.32%	0.12%	2.19%	3.25%	0.00%	2.12%

Table 8. Count of Vehicles by Fuel Type for the Participating States

State	Gas Vehicles	Electric/ Hydrogen	Hybrid	Flex fuel/ Biofuel	Other Fossil	Diesel
Arizona	4,135,600	3,233	84,880	339,843	675	54,765
California	20,563,578	83,213	433,851	267,871	16,508	223,504
Idaho	2,020,931	290	18,014	106,149	197	49,132
Montana	420,969	2	6,378	28,813	83	72,627
Oregon	2,210,772	14	62,342	112,388	160	139,275
Texas	14,594,896	27,018	38,190	2,370,422	455,099	561,590
Utah	1,683,707	1,506	32,797	144,812	2,758	113,941
Washington	3,983,716	5,084	94,684	140,127	167	91,476

For each census tract in the eight states, the percent of vehicles by non-gasoline fuel category was determined based on points within the tract and larger geographies within which the tract fell. This process produced census-tract-level estimates of non-gasoline fuel use that could be combined with the VMT estimates described above.

SUMMARY

The information produced by the VMT analysis and the fuel type analysis are combined for each census tract and then aggregated to provide the state level results discussed at the beginning of this memo. Subsequent task memoranda will explore the differences in travel and vehicle characteristics in different portions of each state. From the results presented here, among the participating states, there are significant differences in fleet composition, which will affect distribution of financial impacts of a revenue-neutral road usage charge.

CHAPTER 2: URBAN, MIXED, AND RURAL DATA ANALYSIS (TASK 4)

The core focus of this section of the report was to identify differences between urban, mixed and rural areas of each participating state, and describe the ways in which those differences may cause a road usage change to affect households differently than the current gasoline tax. In compiling the data to carry out this analysis, we have reviewed some of the literature on the topic and developed the methodological pieces introduced in Tasks 2 and 3 and further described here.

The analysis focuses on identifying as much information at the census tract geography as possible before incorporating higher levels of detail. The vehicle mileage traveled (VMT) and fuel type information prepared for Task 3 is built up from census-tract-level data and will presented in further detail below in the context of households living in urban, mixed, and rural portions of the states.

TRAVEL ESTIMATES TO BE USED IN FINANCIAL ANALYSIS

In estimating the revenue-neutral road usage charge rate needed to replace the fuel tax on gasoline, we used the travel estimates derived from the household VMT estimates and vehicle fuel type mixes presented in Task 3. The VMT for gasoline[16], hybrid and part of the flex/biofuel[17] fleet is presented in Table 9 for each state's urban, mixed and rural portions and will be used to estimate current gas tax revenues.

Table 9. Estimate of Household Annual VMT in Millions Subject to the Gasoline Tax (Gasoline, Hybrid, 50% of Flex/Biofuel)

State	Urban	Mixed	Rural
Arizona	21,102	3,074	1,349
California	141,583	7,683	3,203
Idaho	4,970	1,234	1,218
Montana	2,017	719	1,583
Oregon	12,515	2,280	1,151
Texas	93,168	15,133	6,059
Utah	10,178	492	756
Washington	25,164	4,105	1,709

[16] Gasoline vehicles may utilize fuel with up to 15 percent ethanol content. A major portion of gasoline sold in the United States has up to 10 percent ethanol content, but for the purpose of this study this fuel mix (sometimes referred to as gasohol) is still considered "standard" gasoline and is used by vehicles classified as gasoline-only. Most states tax pure gasoline and gasohol at the same rate.

[17] For this study 50 percent of the fuel used by flex/biofuel vehicles is assumed to be standard gasoline purchased at a retailer who collects fuel taxes. Between and within the eight states, there may be significant differences in the availability of biofuels and the types of flex fuel and biofuel vehicles in the fleet. For some census tracts, all vehicles in this category may be flex fuel vehicles that are always fueled with gasoline. For other tracts, the registered vehicles always use biofuel from non-retail distribution channels. However, sufficient detail to differentiate these circumstances was not available and is beyond the scope of this study. Researchers performed sensitivity tests based on assumptions of 80 percent and 20 percent of flex/biofuel consumption being covered by the gasoline tax and found only negligible impact on equivalent RUC rates and the geographic distribution of financial impacts.

Gasoline-only, electric, hydrogen, hybrid and all flex/biofuel vehicles are considered to be subject to the road usage charge. This will result in including VMT that is not currently subject to any tax regime (shown in Table 10).

Table 10. Estimate of Additional Household Annual VMT in Millions Subject to the Road Usage Charge (Electric, Hydrogen, and 50% of Flex/Bio Fuel)

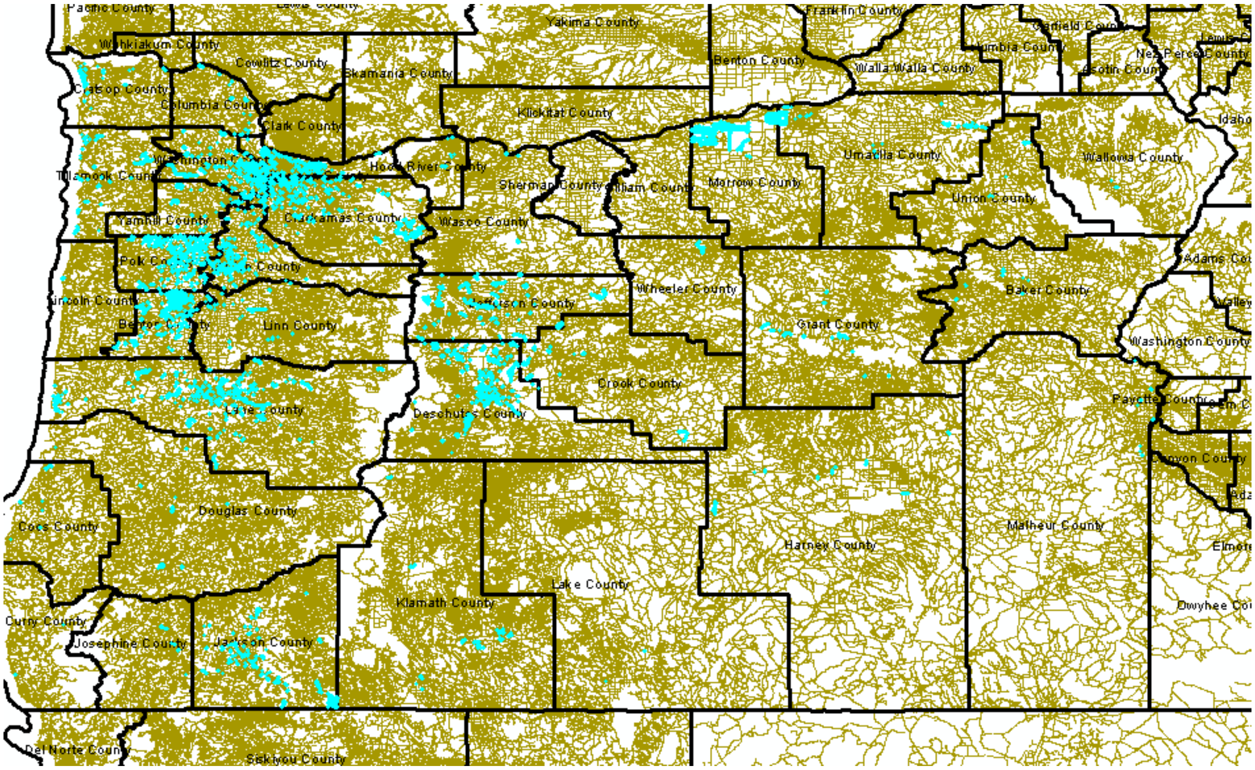
State	Urban	Mixed	Rural
Arizona	736	118	64
California	1,459	81	33
Idaho	127	36	36
Montana	60	20	58
Oregon	287	66	36
Texas	6,502	1,488	726
Utah	403	24	42
Washington	433	84	37

These estimates have not been adjusted for travel on public roads versus private facilities or off-road travel. VMT estimates are based on trips reported in the NHTS during each household's travel day. Neither the NHTS, nor any other surveys we have reviewed, address specifically whether a trip occurred on public or non-public facilities. A question necessary to acquire that data would significantly increase the complexity of an NHTS travel diary, since trips are probably not exclusively on public or non-public facilities. Also, household trip-makers do not necessarily always know the ownership of the facility they are using.

However, w did review data from several states using ESRI's *StreetsMap NA* layers that allowed us to identify private vs public road center-lane miles at the county level. In this data, public roads are only those maintained by a public entity. Other definitions of "public" might refer to "public-use" rather than "publicly-maintained" facilities. Future work that seeks to include adjustments for public roads must explicitly define the relevant meaning of public in the policy context.

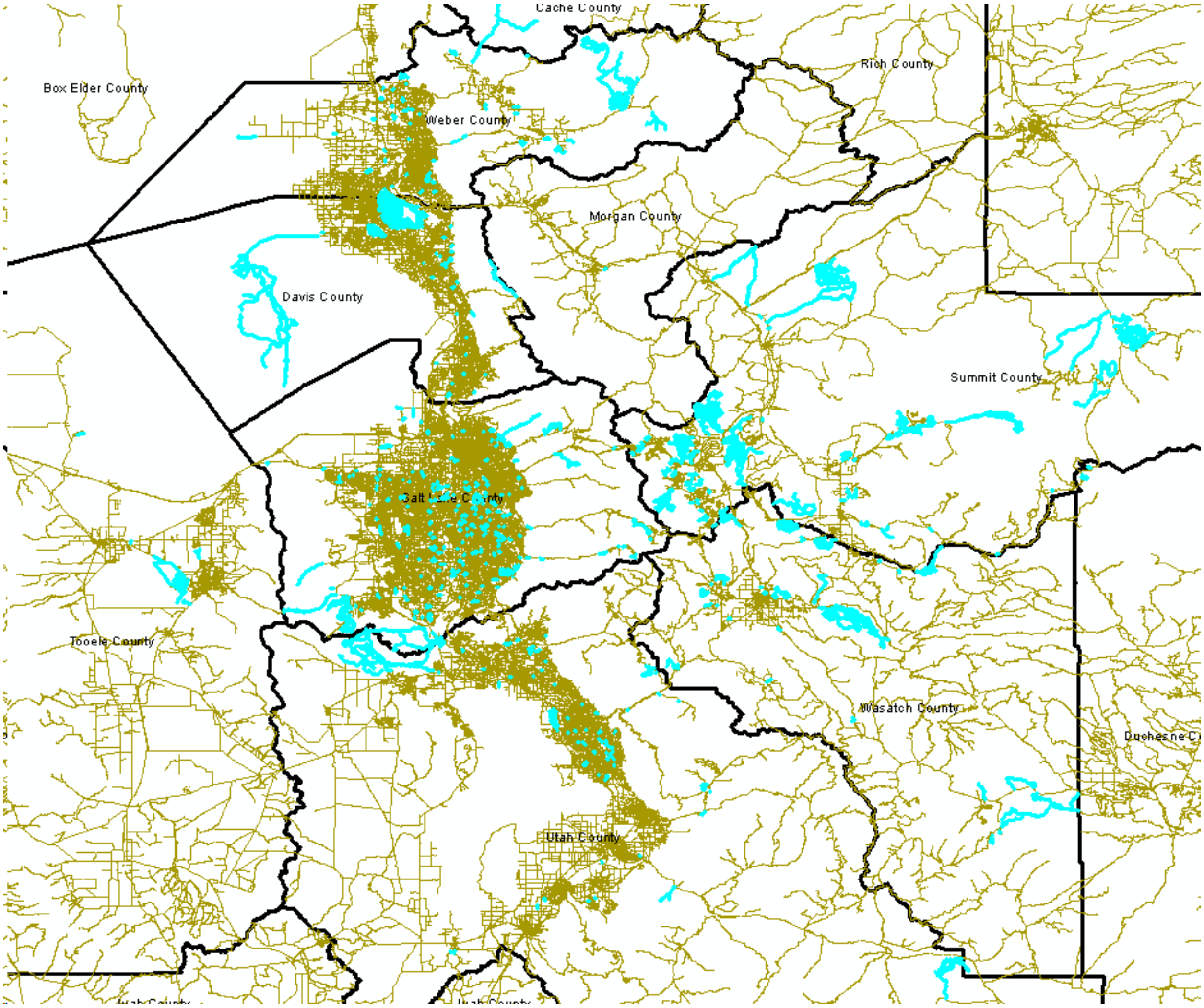
The ESRI data source allowed us to examine the issue of public vs private facilities in slightly greater detail, but could not directly solve the issue of travel on such facilities, because it only includes information on facility length and not on travel volumes. The existence of private facilities alone provides very little information about the amount of travel on non-public roadways or who travels on them.

Figure 1. Selection of non-public streets longer than 200 meters in Oregon using the ESRI StreetsMap NA Layer



As the purpose of this review was simply to understand the issue and not develop data that could be applied to the analysis, we did not review all states due to difficulty in manipulating the very large spatial files of detailed streets information. The initial observations in four states identified several interesting aspects of non-public road facility length. In the case of Oregon (shown in Figure 1), facilities longer than 200 meters and not maintained by a public entity (shown in bright blue) are just as prevalent, if not more prevalent, in heavily settled areas as in less densely populated regions. This was also the case for California, Montana and Utah. Without a minimum length restriction for non-public roads (e.g., the 200-meter cut-off), the ESRI layer shows even greater amounts of privately-owned roadways in urban areas. In Salt Lake County for example, the 2.66 percent of streets highlighted in Figure 2 increases to 11 percent when smaller roadway segments are included.

Figure 2. Selection of non-public streets longer than 200 meters in North-Central Utah using the ESRI StreetsMap NA layer



Even increasing the minimum length threshold to 500 meters (greater than three-tenths of a mile) there are still a significant number of privately maintained facilities in urban areas. This indicates that travel on non-public facilities may be an important consideration not just for rural areas. Again, this source of data does not contain any information on use patterns for these facilities. Urban households may use private facilities outside the cities that are in rural areas, and rural residents may use private facilities within tracts that are classified as urban.

New data sources, such as cellular or GPS data products for transportation planning, or data collected by RUC pilots may offer the level of detail necessary to include consideration of VMT on public vs private facilities in the analysis. However, for this analysis we did not consider the suitability of any of these data sources for use at a statewide and multi-state level.

VEHICLE CHARACTERISTICS FOR THE URBAN, MIXED, AND RURAL PORTIONS OF PROJECT STATES

In addition to the statewide estimates of VMT using different fuel types, we can identify differences in fuel use, fuel efficiency, and vehicle age for the fleets registered in each state's urban, mixed and rural portion using the registration data we have reviewed for the participating states. As discussed in the Task 3 memorandum, when possible all registrations were attributed to specific tracts or else allocated to tracts based on the highest level of geography with which they could be associated.

State vehicle registrations show that non-gasoline-powered VMT as a share of total travel is higher in the rural parts of states than mixed or urban areas. As can be seen in Table 11, urban areas in all eight states for which we have analyzed registrations have the lowest share of non-gasoline powered VMT. In general, this is because diesel and flex fuel or biofuel vehicles are more common in rural areas.

Table 11. Percent Non-Gasoline-Powered VMT by Urban, Mixed, and Rural Portions of States, when Classified by Census Tracts

State	Urban	Mixed	Rural
Arizona	10%	11%	12%
California	5%	5%	5%
Idaho	8%	9%	9%
Montana	16%	20%	24%
Oregon	12%	17%	18%
Texas	17%	25%	28%
Utah	14%	20%	23%
Washington	7%	9%	9%

There is also a consistent pattern in fuel efficiency in urban, mixed, and rural states across all eight states, with urban areas having the highest average fuel efficiency, decreasing across mixed areas, with its lowest value in rural areas. This data is presented in Table 12.

Table 12. Average Fuel Efficiency for Vehicles in Urban, Mixed, and Rural Census Tracts of Project States – Gas-Taxed Vehicles Only

State	Urban	Mixed	Rural
Arizona	22.7	22.1	20.9
California	27.0	26.3	25.2
Idaho	21.7	21.2	20.8
Montana	23.8	23.6	22.9
Oregon	21.3	20.3	19.9
Texas	21.6	20.5	19.9
Utah	22.8	21.8	21.1
Washington	22.6	21.5	21.2

Vehicle age also exhibits a strong trend as we compare urban to rural tracts. In Table 13, rural portions of states have the oldest average age, although the magnitude of the difference varies from state to state. In Arizona, vehicles registered in rural tracts average 4.1 years older than vehicles registered in urban tracts, while the average difference is only 0.3 years in Montana.

Table 13. Average Vehicle Age for Vehicles in Urban, Mixed, and Rural Census Tracts of Project States

State	Urban	Mixed	Rural
Arizona	9.2	9.8	10.7
California	9.5	10.0	11.0
Idaho	13.6	14.2	14.7
Montana	13.0	13.3	13.2
Oregon	10.7	12.9	13.6
Texas	9.1	9.5	9.9
Utah	9.5	10.2	10.7
Washington	12.2	13.0	13.6

Differences in Travel Patterns for Urban and Rural Households

To evaluate and compare driving patterns in urban versus rural areas, we reviewed several statewide household travel surveys for WRUCC members in addition to the National Household Travel Survey (NHTS).

We investigated how trip distance and frequency vary based on different trip purposes in the NHTS (see Table 14) and the Oregon Household Activity Survey (OHAS) (see Table 15). Based on the NHTS Urban-Rural classification using Census Urban Area boundaries, there is little difference between urban and rural households nationally in trip frequencies, but the NHTS shows much longer trip lengths for rural households, including nearly than twice as much travel for shopping trips.

Table 14. Analysis of Urban versus Rural Trip Frequency and Length for Various Purposes in the NHTS

NHTS	Area	Home-based Trips				Non-HB	All Trips
		Work	Shopping	Recreation	Other		
Frequency	Rural	1.00	1.27	0.57	1.13	2.06	6.02
	Urban	0.89	1.26	0.54	1.08	1.69	5.46
Distance per Trip	Rural	15.9	10.4	14.6	12.7	11.7	12.6
	Urban	11.8	5.6	12.2	7.8	9.0	8.7

When using the OHAS data, we calculate rural measures using a household-weighted average of “Rural” and “Rural Near” location types, and urban measures as a household-weighted average of “IsoCity”, “CityNear” and “MPO” location types. The OHAS data also shows rural households taking longer trips, but traveling quite a bit less frequently. This reflects findings in other studies such as the Mineta Transportation institute (MTI) report based on the California Household Travel Survey (CHTS) and Washington State RUC study, which find that although some factors lead to increased fuel consumption for rural drivers, other factors push travel patterns and fuel consumption in the other direction.

Table 15. Analysis of Urban versus Rural Trip Frequency and Length for Various Purposes in the OHAS

OHAS	Area	Home-based Trips					Non-home Based		All Trips
		Work	Recreation	School	Shopping	Other	Non-Work	Work	
Frequency	Rural	1.08	0.24	0.38	0.38	1.24	0.60	0.29	3.91
	Urban	1.13	0.28	0.52	0.52	1.52	1.59	0.38	5.53
Distance per Trip	Rural	13.1	15.2	14.8	10.5	10.2	12.2	14.0	12.0
	Urban	8.7	8.1	8.0	4.0	5.5	9.0	6.5	6.5

In Table 16, we summarize findings from two other regional studies in Washington and California. CHTS data shows that on average rural and urban drivers travel the same distance per day. [18] However, rural households with less than $25,000 of annual income drive less than low-income urban households, and all higher-income categories of rural households drive more than their urban counterparts. Washington State conducted a survey in 2014 using the Voice of Washington State (VOWS) web panel that found significant differences between daily VMT for self-designated urban and rural residents.[19]

Table 16. Daily Vehicle Miles of Travel (DVMT) from Household Travel Surveys

	Urban	Rural
Mineta Transportation Institute Analysis of the California Household Transportation Survey	31.7	31.7
Voice of Washington State Survey for the WA Road Usage Charge Assessment	35.8	60.2

While it is interesting to compare tabulations between the various surveys, both definitions of trip purpose and urban/rural location vary, which could affect mean trip distances as well as frequency calculations. Although trip purpose is often summarized to home-based and non-home-based categories, these vary from survey to survey, and more and more surveys are focusing on much more varied activity codes, such as the 39 California Household Travel Survey activities. These differences in definition highlight the need for a common definition and consensus among WRUCC members in addition to standard survey sampling approaches that establish ranges of confidence levels necessary for interpretation.

For the states within the project region, our estimates provide some additional insight into a subset of the NHTS data summarized above. Use of the urban, mixed and rural designations, as prepared for Task 2, adds an additional level of detail relative to the various urban-rural definitions others have used. In Table 17, we see significantly higher estimated VMT in the mixed tracts, where residents live outside Census Urban Areas but travel into them for work, than in the tracts with more rural travel patterns. This difference is mostly driven by the socioeconomic differences, since most of the mixed and rural tracts are governed by the same set of regression equations. For many of the states the difference between urban and rural tracts, once mixed tracts have been segregated, is not unusually large.

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18 In 2015, the Mineta Transportation Institute (MTI) published a report “Household Income & Fuel Economy in California” that reviewed the fiscal implications of implementing a road user charge (RUC) tax system. The study is based on recent California Household Travel Survey Data, which defines the top 10 counties by population as Urban and the other 48 counties as rural (See http://www.dot.ca.gov/hq/tpp/offices/omsp/statewide_travel_analysis/files/CHTS_Appendix.pdf, pages 15-18)

19 From the Washington State Transportation Commission Road Usage Charge Assessment Household Inventory of Vehicles in Washington State. June & November 2014 Report. DVMT derived from annual total household VMT based on 365 days per year. Urban and Rural are self-designated classifications from survey panel respondents. Survey respondents could also choose Suburban. These respondents have average DVMT of 50.8 miles.

Table 17. Daily VMT per Household in Urban, Mixed, and Rural Tracts, based on EDR Group Estimates

	Daily VMT Per Household		
	Urban	Mixed	Rural
Arizona	37.3	45.8	41.4
California	42.1	46.0	39.4
Colorado	41.8	57.7	46.0
Idaho	44.5	52.6	44.8
Montana	41.0	51.6	42.8
Oregon	38.2	42.6	38.6
Texas	47.4	54.1	44.0
Utah	47.7	59.9	52.6
Washington	41.1	46.3	39.7

Using the regression equations from the Transferability Statistics report, we also see that households in mixed tracts are predicted to travel the most, while households in rural tracts are predicted to take the fewest daily trips. This pattern can be seen for most of the eight states in Table 18.

Table 18. Daily Trips per Household in Urban, Mixed, and Rural Tracts, based on EDR Group Estimates

	Daily Trips Per Household		
	Urban	Mixed	Rural
Arizona	5.4	5.8	5.4
California	5.6	5.9	5.2
Colorado	5.7	6.5	5.8
Idaho	5.8	6.2	5.6
Montana	5.5	6.1	5.5
Oregon	5.1	5.5	5.1
Texas	6.1	5.8	5.6
Utah	6.3	6.7	6.2
Washington	5.4	5.8	5.2

Based on the above two estimates, households in mixed tracts drive the farthest on average for each of their trips. Table 19 shows that in some states, rural is a close second, and that in the coastal states urban trips are estimated to be nearly as long as rural trips.

Table 19. Average Trip Length for Residents of Urban, Mixed, and Rural Tracts, based on EDR Group Estimates

	Average Trip Length		
	Urban	Mixed	Rural
Arizona	6.9	7.9	7.7
California	7.6	7.8	7.6
Colorado	7.4	8.9	8.0
Idaho	7.7	8.5	8.0
Montana	7.4	8.4	7.8
Oregon	7.5	7.8	7.6
Texas	7.8	9.3	8.1
Utah	7.5	8.9	8.4
Washington	7.6	7.9	7.7

SUMMARY

For the states in this study, we see that both vehicle characteristics and predictions of travel behavior vary markedly between urban, mixed, and rural portions of states. An important observation of this work, is that residents of mixed tracts are expected to travel more frequently and longer distances than rural residents. Rural households in most states only drive slightly longer distances per day than urban residents, but are driving in older, less fuel-efficient vehicles, which is expected to lead to higher incidence of the gasoline tax for rural households.

CHAPTER 3: FINANCIAL IMPACTS TO SYSTEMS (TASK 5)

Analysis of the financial impacts of replacing the gasoline tax with a revenue-neutral road user charge (RUC) show that households in rural census tracts will generally pay less under a road user charge than they are currently paying in gasoline taxes. In most states, households in mixed census tracts will also pay less under a RUC. Households in urban residents in all states see a slight increase in payments. Table 20 shows the estimated percent reduction in payments for each state's urban, mixed, or rural areas under a revenue-neutral RUC. Negative reductions represent an increase in payments.

Across the eight states, urban areas are likely to pay between three tenths of a percent and 1.4 percent more under a RUC than the current gas tax. Payments for rural residents are reduced by between 1.9 percent and 6.3 percent, varying by state. These figures are averages for all census tracts within an urban, mixed, or rural category in each state with individual census tracts seeing larger or smaller increases and reductions. These results are attributable to the fact that urban areas account for the greatest portion of total VMT in all states; the increase in their payments under a RUC represents a smaller percentage of their current estimated gasoline tax payments than the reductions for mixed and rural residents.

Table 20. Reduction in Payments Under RUC Compared to a Gas Tax

State	Urban	Mixed	Rural
AZ	-0.7%	1.7%	6.1%
CA	-0.3%	2.4%	6.3%
ID	-1.0%	0.9%	3.1%
MT	-1.4%	-0.4%	1.9%
OR	-1.0%	2.9%	4.8%
TX	-0.5%	1.6%	3.1%
UT	-0.6%	3.4%	5.5%
WA	-1.0%	3.6%	4.8%

The census tracts designated as mixed generally pay less when moving to a RUC. As shown in Table 21, the only state that may collect more revenue from mixed areas is Montana, where the difference is almost negligible. The reductions in payments under a RUC for mixed areas are greater than rural areas in some states and less in others, depending on the number of households in mixed tracks and their travel patterns and vehicle type characteristics.

Table 21. Gasoline Tax Paid Minus Road Usage Charge Paid by Urban-Mixed-Rural Regions ($)*

State	Urban	Mixed	Rural
AZ	-1,123,000	417,000	706,000
CA	-4,504,000	2,103,000	2,401,000
ID	-754,000	171,000	583,000
MT	-331,000	-33,000	364,000
OR	-1,813,000	985,000	828,000
TX	-4,276,000	2,415,000	1,861,000
UT	-806,000	223,000	583,000
WA	-4,768,000	3,047,000	1,721,000

*(*Negative values indicate that households will pay more under a RUC.)*

The changes in revenue for different Urban-Mixed-Rural portions of states are based on the fuel tax rates that were provided by states and the equivalent RUC, which was calculated to be revenue neutral. Both are presented in Table 22. Calculation of the revenue neutral rate includes additional VMT attributable to electric, flex fuel and biofuel vehicles, which were assumed to not be previously paying any gasoline tax.[20] The analysis does not assume any changes in travel demand by household in response to changing costs of travel. Several previous studies have examined dynamic VMT modeling and determined that there is negligible impact on results despite significant increases in model complexity.

Table 22. Comparisons of Gas Tax and Road Usage Charge Rates for Participating States

	Fuel Tax	RUC
State	$ Per Gal	$ Per Mile
AZ	0.180	0.0077
CA	0.300	0.0110
ID	0.320	0.0145
MT	0.270	0.0112
OR	0.300	0.0139
TX	0.200	0.0087
UT	0.294	0.0125
WA	0.445	0.0195

Total gasoline tax paid by in-study vehicles was estimated based on the fuel consumption derived from the VMT and fuel efficiency estimates discussed in Memo 4. Table 23 shows what these estimates are for each state and their Urban-Mixed-Rural census tracts. Total statewide gasoline tax estimates in this study

20 For this study, fifty percent of flex- and biofuel vehicles are assumed to pay gasoline taxes with the other 50 percent using alternative fuels. This latter share of flex- and biofueled vehicles will be captured by a RUC and are included in the RUC equivalent charge calculations. If more flex- and biofuel vehicles are assumed to be covered by the current gasoline tax, savings attributable to a RUC would tend to decrease slightly for mixed and rural tract residents. The amount of the savings depends on gasoline consumption rates by flex fueled vehicles and the percentage of these vehicles operating in each census tract. For states with low flex fuel vehicle penetration, the effect on equivalent RUC rates of changing the 50/50 assumption would be small, and for states with high levels of flex fuel vehicle penetration, the effects on savings shifts in payments between urban, mixed and rural areas for all households would be larger. Across a full range of assumptions, from high to low shares of gas use by flex-fuel vehicles, payment increases for urban areas remain small.

are not expected to be equivalent to actual gasoline tax revenues for each state because this study does not include purchases of gasoline by commercial fleets, medium and heavy duty trucks, and household uses of gasoline for non-transportation purposes.

Table 23. Estimated Gas Tax Paid by In-Study Vehicles in Urban-Mixed-Rural Portions of States

State	Urban	Mixed	Rural	Total
AZ	167,425,000	25,052,000	11,612,000	204,089,000
CA	1,572,400,000	87,694,000	38,082,000	1,698,176,000
ID	73,177,000	18,600,000	18,766,000	110,543,000
MT	22,837,000	8,209,000	18,673,000	49,719,000
OR	176,391,000	33,642,000	17,357,000	227,390,000
TX	864,562,000	147,308,000	61,012,000	1,072,882,000
UT	131,008,000	6,649,000	10,524,000	148,181,000
WA	495,607,000	84,921,000	35,865,000	616,393,000

Estimated statewide gasoline tax revenues were then divided by the estimated statewide VMT subject to a road usage charge to establish an equivalent and revenue neutral rate of gas tax revenues per statewide VMT. This rate was then applied to the portion of VMT occurring in each region to determine total payments under a road usage charge as presented in Table 24. Comparison of estimated payments under the current gasoline tax and a road usage charge allows derivation of the impacts presented in Table 20 and Table 21.

Table 24. Estimated Road Usage Charge Paid by In-Study Vehicles in Urban-Mixed-Rural Portions of States at an Equivalent Rate

State	Urban	Mixed	Rural	Total
AZ	168,548,000	24,635,000	10,906,000	204,089,000
CA	1,576,904,000	85,591,000	35,681,000	1,698,176,000
ID	73,931,000	18,429,000	18,183,000	110,543,000
MT	23,168,000	8,242,000	18,309,000	49,719,000
OR	178,204,000	32,657,000	16,529,000	227,390,000
TX	868,838,000	144,893,000	59,151,000	1,072,882,000
UT	131,814,000	6,426,000	9,941,000	148,181,000
WA	500,375,000	81,874,000	34,144,000	616,393,000

There can be significant variation in the impacts within the urban, mixed and rural census tracts of each state. The impact on any specific census tract depends on that tract’s VMT estimates based on the socioeconomic characteristics, fuel type and fuel efficiency estimated using vehicle registration data. To show the variation between tracts, this memo includes maps of the percent change in payments for each state.

Chapter 4: Documentation For Analysis (Task 6) and Tool (Task 8)

This chapter reviews the information collected and analyzed by the research team for this project as well as the methodology employed for our analysis. However, the focus is on the components of and guidance for using the Excel workbook designed as a financial impact tool to replicate the report analysis. Use of the tool and the analysis provided in the earlier task reports is reconciled and clearly documented in the applicable sections. Structuring the descriptions of data and methods around the Excel tool help relate the analysis to a data structure that many readers will be familiar with and will maximize the future value of this document.

Workbook Tool Overview

The tool is a macro-enabled Excel workbook which uses the Visual Basic for Applications (VBA) programming language to increase the tool's flexibility and robustness, and improves its structure and efficiency. The subroutines and functions developed for this project can be found in Appendix E: Code or by opening the Visual Basic Editor to view the code module in Excel.

The tool is designed with the intention of calculating the equivalent "revenue-neutral" per-vehicle-mile Road User Charge (RUC) that would be needed to replace the current gasoline tax, and reporting the urban, mixed, and rural distribution of benefits for a single state at a time. If using the tool to examine sub-state regions or regions that cross state boundaries, the user is advised to interpret the results with care.

Use of the tool is relatively straightforward with two types of inputs needed before running the tool. These are the steps of an analysis using this tool:

1) Gather and organize necessary data for input into the tool
2) Enter prepared inputs:
    a. 12 vehicle variables for each census tract in your state on the "Vehicles" tab
    b. 10 demographic variables for each census tract in your state on the "Demographics" tab
3) Press the "Run Analysis" button on the "Results" tab
4) Review results for your state and census tracts

As described in the reports covering other research tasks developed in conjunction with this tool, geographic units greater than the census tract significantly obscure variation in travel patterns and vehicle ownership in different portions of the state. Like the reported analysis, tool estimates are based on a representative household profile for each census tract. This household is assigned a composite vehicle profile representing vehicle registrations in that tract. We assume all vehicles are registered at the location at which its owner resides. This document will describe how to prepare inputs at the census tract geography and interpret and use the regional and census tract results.

TOOL DESCRIPTION

The tool is divided into three sections: 1) inputs sheets designated by blue tabs, 2) results sheets designated by green tabs, and 3) static data tabs represented by orange tabs. For census tracts where demographic inputs, vehicle inputs, and static data are available, the tool will estimate an annual payment level under current gasoline taxes and under an equivalent road user charge. The difference between these payments is calculated for each census tract and for all urban, mixed, and rural tracts.

The inputs section of the tool consists of two worksheets: 1) "Vehicles" and 2) "Demographics." Both worksheets require inputs at the census tract level. The worksheet structure and preparation of the necessary data are described under the heading Input Data. Preparing data for input to these worksheets represents work that was done by the researchers for the eight states of the study, but which will need to be done by future analysts independently of the tool.

The results section of the tool consists of two worksheets: 1) "Results" and 2) "Calculations." The statewide results for urban, mixed, and rural areas are reported in the "Results" sheet, along with the statewide per-mile charge that would be equivalent to the current gasoline tax. Results at a census tract scale can be found on the "Calculations" sheet for use in mapping, visualization, and further analysis. Additional details are available under the heading "Results Description." These worksheets and their associated code replicate considerable portions of the study analysis in a dynamic matter for each state analyzed using the tool.

Three additional worksheets store essential data which was developed for project reports. These values have been standardized and expanded to allow for use of the tool with other states beyond the eight for which reports were completed. The data is based on the 2010 census geographies and derivative products associated with 2010 data. This data is now static and can be used with any state. More information about these data are described in the "Data Sources" section.

STRUCTURAL DIFFERENCES BETWEEN THE TOOL AND COMPLETED STUDY

The researchers developed a series of programs using the R computing language to analyze the eight states covered in the reports for this project. R was chosen as a more efficient language for handling multiple states and the large number of records involved with some of the states. R also simplified the reporting of intermediate results aggregated to the tables that where were included in reports.

The Excel-based tool reproduces that analysis framework but has some differences, the first of which is the single state design concept. Other differences will be noted when necessary.

Although some of the intermediate calculations were performed in a different order or assignments were made using different methodologies, results are nearly identical. The R code was developed for one analytic component at a time and used for several of the earlier reporting components of the research. R scripts were also essential tools for exploratory data analysis and data cleaning. In comparison, the VBA code and Excel workbook were produced after the analytic structure had been finalized. The workbook is more straightforward than the earlier R-based approach in that it does not store intermediate calculations that do not affect results.

The final dataset for the R-based analysis had over 84 attributes for each census tract. Numerous attributes were dropped during analysis or came from other data tables. Most of these values were initially produced for exploratory reasons, and were not used, or used only for reference, in the final products. Only census tract information directly used in the computations supported by the Tool were retained. The rest were not informative to a tool user and would decrease the tools usability for answering the core research question of spatial distribution of financial impacts under a calculated equivalent rate.

INPUT DATA

All inputs for this tool must be prepared at the census tract level. This process should be relatively straightforward for the "Demographics" inputs and may require some additional manipulation of vehicle registration information for the "Vehicles" inputs. The worksheets are structured with rows representing census tracts and each input sheet’s data attributes in the columns.

If any tract is provided in one of the input sheets but not the other, it will be excluded from the analysis due to insufficient information to estimate travel patterns and associated payment levels. Tracts may also fall out of analysis, if they were unpopulated in 2010 and consequently not included in the analysis used to produce urban, mixed, and rural classifications and associate tracts with the correct VMT generation equations.

Tracts must be identified by the 11-digit code that combines the 2-digit state FIPS, 3-digit county FIPS and 6-digit tract code. Ideally, these IDs will be entered as text to preserve leading zeros. However, the tool can interpret and convert 10- and 11-digit numeric inputs.

Vehicles

The analysis is based on 12 census-tract level vehicle variables. For each of six fuel type categories, two measures are required: the percent of tract vehicles which belong to that fuel category and the average fuel efficiency of tract vehicles in that category.

The six fuel types are:

1) Gasoline (pays gas tax and RUC)
2) Hybrid (pays gas tax and RUC)
3) Electric or Hydrogen (pays only RUC, could be used to include other vehicles or fuel types that are not captured by gas tax but would be by RUC)
4) Diesel (excluded from scope of analysis)
5) Flex- or Biofuel (half of travel assumed to use gasoline and pay gas tax and the other half added in when RUC calculated. Tool users can adjust the 50% split. This category could be used to capture other vehicle or fuel types that are partially captured by current tax structure but better captured by RUC.)
6) Other Fossil Fuels (assumed to not be captured by gas tax or RUC, conceived to capture CNG, LNG, Propane, LPG, etc. vehicles, but could be used to capture other vehicles excluded from scope of analysis as well)

There are many possible sources of information for the data needed in this part of the analysis, but the end product is three pieces of information for each in-scope registration in the state: fuel type, fuel efficiency, and census tract of registration. Once each vehicle record has these data attributes vehicles can be summarized by tract to produce the information need for the tool.

Additionally, out-of-scope vehicles should be removed from the analysis pool. Fuel type must be determined before fuel efficiency. However, the other two processes can happen at any time in the vehicle analysis, and in fact it may take several iterations for the analyst to feel comfortable that all in-scope vehicles have been separated from out-of-scope vehicles.

If fuel type is not available in the registration data available for analysis, it will likely need to be determined by decoding VIN records. The main source of fuel efficiency information is the EPA Fuel Economy.gov database for all model years. Relatively few cars in regular use were produced before EPA began testing fuel economy. Since past fuel economy ratings have been updated to conform to current testing regimes, EPA data is comparable over time. If address information is available, this can be geo-coded to specific locations and assigned a census tract in a bottom up approach. If only zip code or county of registration is available, a top down allocation to census tracts will be necessary.

Collecting Core Vehicle Information and Linking to Fuel Economy

To match a vehicle's fuel economy with the EPA database, generally at least make, model, model year, and fuel type are needed. Additional information such as number of cylinders, engine displacement, and transmission type may be useful. Depending on the information collected by the state agency in charge of vehicle registrations, some of the information required for determining fuel economy may be available immediately. Several of the states included in the initial study could provide fuel type and usable make, model, and year information. Other states were only able to provide VINs.

When working with only VINs, or VINs and less detailed make, model, and year information, it will be necessary to use a VIN decoding application. There are several commercially available services, but the NHTSA Product Information Catalog and Vehicle Listing (vPIC) products provide a robust publicly available service for VIN decoding.[21] There are several different tools available through an API collection for batch processing VINs.[22] When decoders fail to provide information on a vehicle, it can either be assumed to be out-of-scope as decoders should cover most household vehicles from the last 30 years. Alternatively, available information for similar vehicles from the registration database can be used to make assumptions about fuel type and fuel efficiency.

In some cases, decoded or source vehicle information will match perfectly with EPA records. In other cases, it will be necessary to use a process we refer to as using "fuzzy lookups". This process involves building linkages from the remaining problematic data you have to the EPA database entries by a process of using approximate matches rather than straight lookups. This is because of a few potential differences including:

1. The reporting and detail of the vehicle model (such as inclusion of number of doors, engine type) causing non-exact matches that a normal 'lookup' would simply miss.
2. Differences in abbreviations used in raw, decoded, and EPA data.
3. EPA not retesting vehicles which have no changes between model years, and consequently only including a record every few years.

[21] See https://vpic.nhtsa.dot.gov/ all tools and descriptions and https://vpic.nhtsa.dot.gov/api/ for the API.

[22] For the eight-state study, API calls were made from an executable Visual Basic program with several options for interaction through a development environment console. All vehicles within the study were decoded from VIN information in order to apply a more consistent methodology across states.

There are several options to resolve imprefect matches, including the method we employed, which was to use a jaccardian weighting tool to do our matching.[23] When making imperfect matches it is important to balance additional matched records with the risk of false positives. If too many records are matched to a fuel efficiency that is not close to the actual record, it could make statewide financial impact results less accurate than simply excluding those records.

If a relatively strict fuzzy lookup fails to produce additional matches betweent the data sets, it may be necessary to manually review records. Hopefully, at this point the majority of records have been successfully matched and there is some concentration of unmatched records. For example, in one state there were hundreds of Dodge RAM pickup trucks unmatched because EPA model names included whether vehicles are 2WD or 4WD. This alone could have been resolved by a fuzzy lookup, but other inconsistencies in model names meant these records came up for manual review and were a realtively easy fix. Manual review may also result in discovering that out-of-scope vehicles are the major issue.

When working with multiple states data, the researchers were able to make comparisons across databases that filled in some missing information. Appendix D: Vehicles describes the processes of leveraging the strength of different state databases.

Determining the Universe of In-Scope vehicles

Vehicles like trailers and heavy truck chasses, which are unlikely to be covered under the same tax/fee structure as passenger vehicles, will also fail to match with EPA fuel efficiency information. For both of these reasons, at some point in the process they should explicitly be removed from the dataset of interest. While many analysis workflows may result in them dropping out when they fail to join, match or merge with some other data attribute, it is probably better practice to explicitly remove them and document or otherwise flag these records.

If information about vehicle type is available in registration information, it may be resource efficient to remove out-of-scope vehicles before using a VIN decoding tool. These vehicles will need to be removed eventually, and after attempting to decode them, there will be additional extraneous information attached, unless they simply fail to match with anything in the decoder tool. See Appendix D: Vehicles for the vehicle type prescreening completed by the research team.

In addition to vehicle information for looking up fuel efficiency, vPIC will also provide information on vehicle type. If vehicle type information is not available in registration data, be sure to use vPIC output (or results from another process) to remove vehicles such as golf carts, heavy vehicles, and mopeds from the later analysis steps. We did find that in some cases vehicle classifications from source data did not match with vehicle classifications in decoded data. Depending on time and resource constraints, it may be desirable to run all registrations through a decode and see which type classification seems more dependable. Even if vehicles are removed before decoding, it is likely that some additional vehicles will be identified as out of scope after collecting more information through the decoding process.

Spatial Assignment

Depending on the level of geographic/address detail available, it may be possible to geocode registration locations precisely and assign them to the appropriate census tracts. In other cases, it may be necessary to share out registrations at a zip code or county level to census tracts based on the number of households composing each tract as a proportion of the wider geography.

[23] If working in an Excel environment, the following site provides an explanation of the insufficiency of the built in functions and an add-in from Microsoft for fuzzy lookups similar to the ones used for the study: http://www.excel-university.com/perform-approximate-match-and-fuzzy-lookup-in-excel/.

If multiple types of location information exist, data most related to a household's location of domicile should be used. If only mailing addresses are available, it will be necessary to accept some minor error in correlating household vehicle ownership patterns with household travel patterns.

The researchers dealt with five different types of spatial assignment, which include most of the scenarios future analysts might face:

- Census tract provided by source agency
- Point (provided by source agency) to tract
- Address to point to census tract
- Zip code to census tract
- County to census tract

Any point-based assignment to census tracts is preferable to a down allocation. Down allocation may require assigning fractions of less common fuel type vehicles to each tract within the larger geography. Geo-coding of addresses and assignment of points to tracts can be done using a number of products. For the eight-state study, analysts used ESRI's Streetmap North America locators in ArcGIS. ArcGIS also has a default set of locators.

However, even when working with data that provides full address information, some registrations were not able to be located at a finer level of geography than the county. This could be due to spelling or typographical mistakes in the entries, inconsistencies between different levels of the address information (such as impossible zip code – county pairings), or simply a lack or sufficiently detailed information. In these cases, unassigned records will probably need to be collected to pass through a more aggregate assignment strategy.

County registrations were shared out by the number of households in each tract relative to the county-wide number of households. This can be done with the census tract household data discussed in the Demographics section, since tracts are subdivisions of counties, and borders are coterminous.

Zip code assignment in more complicated because zip codes are based on line-based delivery routes that are only imperfectly converted to polygons, and not coterminous with census tract boundaries. There are several data products available to establish a crosswalk between zip codes and census tracts.[24]

Any records that cannot be spatially located or are determined to be outside the state or region of interest should be noted and tracked to understand differences in vehicle inputs at the beginning of the matching process and the set of vehicles summarized for the final tool inputs. Registrations located outside the state are not usable because they cannot be correlated with the estimated VMT generation for in-state census tracts. There is no purpose in distributing unassigned vehicles across the state, since the goal of the analysis is to examine within-state geographic differences.

Demographics

Each tract must be associated with 10 demographic variables drawn from decennial census or ACS data products from the Census Bureau. These variables were identified as valuable in estimating household

[24] The analysis for the reports utilized crosswalk files from the Census Bureau, available at https://www.census.gov/geo/maps-data/data/zcta_rel_download.html. This crosswalk uses Census' 2010 Zip Code Tabulation Areas, rather than using raw zip codes. The Department of Housing and Urban Development also publishes crosswalks between USPS ZIP codes and census tracts, which they update quarterly based on changes to ZIP Codes. See: https://www.huduser.gov/portal/datasets/usps_crosswalk.html.

daily VMT generation by the Bureau of Transportation Statistics when they calculated the 2010 NHTS transferability statistics in the paper Local Area Transportation Characteristics for Households.[25] A subset of the 10 measures are used for each tract depending on its geographic location and characteristics.

The 10 variables (census table and line numbers in parentheses) are as follows:

1) Count of Households (B11005 line 1)
2) Median Income (B19013 line 1)
3) Count of Household Vehicles (B25046 line 1)
4) Total Population in Households (B11002 line 1)
5) Owner-occupied Homes (B25009 line 2)
6) Number of Workers (B08137 line 1)
7) Households with at least 1 child under 18 (B11005 line 2)
8) One-person households, under 65 years old (B11007 line 8)
9) Multi-person households, no members over 65 years old (B11007 line 9)
10) Multi-person households, at least 1 member over 65 years old (B11007 line 4)

These data can be acquired via table searches on American Factfinder or from Census' Summary Files available from their FTP site.[26] Depending on the familiarity of the analyst compiling demographic data with summary files, it may be faster to pull individual tables from American Factfinder. For multi-state analysis, the advantages of processing data from summary files increases. The report analysis is based on 2009-2013 ACS summary files processed with an R script. The tool has been tested for multiple states using this demographic data.

To use American Factfinder:

1) Navigate to factfinder.census.gov.
2) Click "Advanced Search" and "Show Me All."
3) Enter the table number from the list above in the search boxes under step 1. Do not input a geography.
4) Use the "Geographies" filter accessed from the left side of the webpage to select all census tracts in your state.
5) Select the table corresponding to five-year estimates for the data year you are interested in.
6) Download the data as .csv file.
7) Repeat for each table needed, as listed above.
8) Compile data from individual files into format of inputs sheet "Demographics."

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[25] See http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/subject_areas/national_household_travel_survey/about for a brief description or http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/subject_areas/national_household_travel_survey/methodology to access the final technical documentation from the project.

[26] The site can be accessed at http://www2.census.gov/. The reports for the eight states included in the study utilized the most current 5yr data available at the time, downloaded from the acs2013_5yr folder on the FTP site.

In some cases, the Census Bureau may suppress some of these variables or have not collected enough information to impute them. An analyst using the tool can independently impute these values or allow them to drop out of the analysis. The tool removes tracts with missing values to prevent calculations from being invalidated. In the researchers' experience, most of the tracts with missing values have very low household counts and should not have significant impacts on the analysis whether included or not.

Difference: The R code for this project imputed missing values of household income and the number of vehicles in the tract. For tracts with missing data, the mean number of vehicles per household and the median household income in areas of that state with the same Urban-Suburban-Rural[27] classification was assigned.[28]

Note that the information contained in the "Tracts" static data worksheet uses the census tract codes used in the 2010 census. Please check if your state has had any tracts with IDs that were changed or corrected since the 2010 Census.[29] If any tracts have been corrected, they will need to be renamed to match the data in the tool to prevent dropping from the analysis.

DATA SOURCES

The "Equations" tab includes the 18 individual household daily VMT generation equation coefficient sets from the BTS NHTS Transferability Statistics report.[30] There is one equation for each of six geographies based on census divisions and regions which were divided into urban, suburban, and rural components. The equations are organized with a row representing a geographic area and the columns containing coefficients for estimating daily household VMT in that area.

The worksheet further contains the default annualization factor and default inclusion factor for flex- and biofuels, two other factors used in the report analysis. The use of these factors is explained under the Tool Calculations section on page 29. The orange cells containing these two values may be updated but the equation coefficients are protected to avoid accidentally changing any of the VMT generation factors. As mentioned in the Task 3, 4, and 5 reports modification of the inclusion factor will slightly change distribution impacts. However, modifying the annualization factor will only affect the statewide level of estimated revenue collected, which are equal under both the gas tax and RUC cases by definition.

The "States" tab has two main purposes. It is used for lookups to determine which of the six census region/division geographies a tract belongs in when selecting VMT generation equation. It also contains the states' fuel tax rates. The workbook contains rates as of January 2016, with a few modifications to be consistent with the rates which the eight states participating in the original analysis requested be used. These rates can be updated to reflect future changes to rates. The notes column is also unlocked to allow a record of any changes to the notes. Changes to other portions of this sheet are locked, because the regional classifications are static as of the time of the Transferability Statistics report and accidental changes to the lookup values or return values on this sheet could make the tool unusable.

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27 See Calculation of Tract Classifications on page 5 for descriptions of this classification scheme.

28 For the eight states, Vehicle ownership was imputed for 243 tracts and income was imputed for 25 tracts.

29 Boundary changes or name changes can be found at https://www.census.gov/geo/reference/boundary-changes.html. For the eight-state analysis, names had to be reconciled for 7 CA tracts and 1 AZ tract.

30 See footnote 25 on page 3 for information on the Transferability Statistics Report.

Calculation of Tract Classifications

The "Tracts" tab contains three data attributes for all of the tracts in the United States. The first value is the Urban/Suburban/Rural classification used by BTS for the Transferability Statistics.[31] Tracts are looked up and matched to this value when choosing a VMT generation equation.

The researchers replicated this index for all tracts in the U.S. for the convenience of future tool users. The classification is based on whether a tract is within a Census-classified urbanized area or urban cluster as well as the population density of the census tract. A tract is considered to be within an urban area if its geometric centroid is within the polygon area. This assignment was done by the researchers using the ArcGIS for Desktop Select by Geography tool. The researchers used the population densities already calculated by USDA in the RUCA code file for the 2010 Census[32]. This information was combined using and R script.

The second attribute is the Rural-Urban Commuting Area (RUCA) codes developed by the USDA Economic Research Service. See the Task 2 report for more information on the development of the RUCA codes, which are based on the Census Bureau's urban area classifications and data on commuting patterns for residents of each census tract. As described in the Task 2 report, the researchers derived the third attribute in the "Tracts" sheet – the Urban-Mixed-Rural classification used for this research – from USDA's RUCA codes.

All of these tract attributes are static and based on 2010 census data. A dedicated analyst could possibly upload an updated dataset to the Urban-Suburban-Rural classes based on more current density information, but the other component of that measure, urbanized area boundaries, will not be updated until following the 2020 census. Likewise, RUCA codes could be updated based on more current commuting pattern data, but not the geographic boundaries across which they are measured. Due to these factors, the "Tracts" worksheet is protected to avoid accidental changes to the data. If someone does spend time adjusting classifications or wishes to use a different classification for statewide results, the sheet can be unprotected.

RESULTS DESCRIPTION

The main "Results" sheet of the tool contains three major features:

1) The "Run Analysis" button,
2) The equivalent per-mile charge calculated in the program and used to calculate RUC paid by each census tract, and
3) The state-wide (or regional) changes in payment incidence across urban, mixed, and rural tracts.

The "Run Analysis" button is associated with a VBA subroutine names RunAnalysis() that runs a series of data manipulation and calculation steps to prepare the analysis and present results. Many of the workbook functions were moved to VBA due to the necessity to work with census tract data that changes in size from state to state. This worksheet is protected because both calculations and display of results is dependent on data attributes being available at fixed locations.

The Urban-Mixed-Rural table presents four aggregate measures - three in dollar terms and one as a percent change. Estimated payments under the gas tax will not correspond to total collections reported

[31] See footnote 25 on page 3 for information on the Transferability Statistics Report.

[32] This file can be downloaded here: http://www.ers.usda.gov/data-products/rural-urban-commuting-area-codes.aspx

from other sources since this analysis does not include commercial vehicles, diesel taxes, or some other fuel uses that might result in payments to the gasoline tax accounts. A positive difference in the 4th column represents increased payments under a RUC relative to the gas tax. The 5th column converts this difference to a percentage of the estimated gas tax baseline. Both of these columns sum to 0 as the analysis is based on the estimate of a revenue neutral rate. For any users to pay more, others must pay less.

Just as the tool calculates impacts for the urban, mixed and rural portions of states by adding up total estimated gas tax and total estimated road usage charge revenues in each region, the report analysis in R code summed payments across census tracts in each area type before calculating differences. The differences on a tract by tract basis were mapped for the analysis and can be seen on the "Calculations" worksheet.

Tool Calculations

At the individual tract level, there are seven steps to the development of the data for calculating changes in incidence among urban, mixed, and rural portions of the state. The "Calculations" tab also includes two additional computations of differences in payments that can be used to visualize results and calculate additional measures.

Upon pressing the "Run Analysis" button on the "Results" sheet, the "Calculations" sheet is automatically populated with the census tracts that are viable for the analysis. Cleaning of old data from the sheet is also automated and application of all formulas will take place to match the range of viable census tracts upon execution. The process of selecting the appropriate Census tracts for use in each stage of calculation based on the sufficiency of information is a major component of both the Excel tool and the analysis done using R. The protection on this sheet ensures that all equations remain in place. The automation features prevent any need to manually input data on this worksheet.

Because the tracts for which impacts are calculated included only the intersection of three listings of tracts, the row containing a given tract in the "Calculations" worksheet most likely does not align directly with the row numbers in the "Vehicles" and "Demographics" sheets. Consequently, most of the functions in the "Calculations" sheet utilize VLOOKUPS on the input data attributes. The analysis in R used similar merge procedures to line up data among sources after formatting them in a like manner.

The first calculation step, contained in column B, is to apply the transferability statistic equations to the demographic information provided by the tool user in the "Demographics" sheet. A custom household daily VMT derivation function was coded in VBA to correctly line up demographic inputs with the appropriate equations and regression coefficients. The function can be found in Appendix E: Code as the function called HHDVMT(). See BTS's technical report for a full description of the functional form and derivation of these equations.[33] For each area type, the coefficients can be reviewed in the "Equations" sheet. Use of the equations requires normalizing many of the demographic counts collected for the "Demographics" inputs by the number of households and in some cases taking the log of household income.

The second step is to annualize the daily VMT value. BTS estimates apply to weekday travel in the National Household Transportation Survey (NHTS), and, by default, this analysis utilizes a ratio of weekday VMT to annual VMT calculated from the NHTS. The factor is 294.11 weekday-equivalent travel-days per year. If a user desires, the annualization factor can be adjusted in Equations!B23.

[33] See footnote 25 on page 3 for information on the Transferability Statistics Report.

The third step is to scale household annual VMT to consider all households in the tract. To scale household to tract VMT, the value must simply be multiplied by the total household count provided in "Demographics," since the equations provide point estimates of VMT for a representative household.

The fourth step, in column E, estimates tract fuel consumption based on the portion of vehicles that are gasoline, hybrid, or flex/biofuel and each fuel types fuel efficiency. Fuel efficiencies are input in "Vehicles" as MPG ratings and converted by the equations to gallons of fuel use per mile. Gallon per mile values are applied to the tract's annual VMT estimate to estimate total fuel consumption. By default, 50 percent of flex/biofuel mileage is assumed to be attributable to using gasoline on which a gas tax is paid. This percentage can be adjusted, if desired by the user, in Equations!B24.

The fifth step looks up the state gas tax rate from "States" and applies it to the fuel consumption to estimate fuel tax paid.

The sixth step is calculating an equivalent (revenue-neutral) RUC rate. In column G, the amount of VMT subject to the RUC is calculated as the percent of vehicles using gasoline, hybrid, electric/hydrogen, or flex/biofuel engines times total annual tract VMT. This value is essential the equivalent rate calculation, which is stored in the "Results" tab at cell B3. The rate is calculated using the VBA subroutine GetEquivRate() as the total payments estimated under the fuel tax divided by total eligible VMT under the RUC.

As the seventh and final analytic step, payments by each tract under the RUC are calculated based on VMT subject to the RUC and the equivalent rate. These payments and the gas tax payments can then be used to calculate the aggregate results by portion of the state in the "Results" sheet. These results are aggregated by the VBA subroutine sumUMR().

For the user's convenience, the difference in payments and percent change relative to the gas tax baseline are also calculated in columns I and J. These can be used for mapping at a tract level for calculating other dimensions of impact measures.

Additional Calculations Provided for Initial State Studies

In Chapters 1-3, as prepared for the original set of states, values such as the total amount of non-gasoline VMT and its percent of total travel were calculated for each state. These results are not replicated by the tool, because they are not central to the research question. Some kinds of non-gasoline vehicles may still pay gasoline tax, and other types of non-gasoline vehicles were outside the scope of the proposed road usage charge and don't have any impact.

Just as the tool does not compute measures for total non-gasoline percent of vehicles of VMT, it does not report VMT for each fuel type as can be found in the report. Rather step 4 of the tool analysis directly calculates fuel consumption for vehicles paying the gas tax. These calculations can all be made using the information in the Excel tool but would considerably reduce its readability.

Chapters 1-3 contain tables discussing urban, mixed and rural patterns of travel and distributions of VMT. These are interesting for comparing states but do not show too much useful information in the context of the tool.

Additional vehicle information is also summarized in the report tables, including penetration of non-gasoline vehicles and average fuel efficiency by urban, mixed, or rural classification, which could be derived using the information in the tool. However, the average vehicle age by urban, mixed, or rural classification required additional analysis of vehicle information that is not requested as an input to the tool and was not used in the main line of analysis for the reports.

These results, except vehicle age, were produced for the report analysis by storing intermediate calculation results and aggregating them for the tables and could be done using the spreadsheet tool if so desired.

The reports also contain a considerable number of maps which were created from census tract level outputs. Appendix C of the Task 3, 4, and 5 report could be created from the "Calculations" worksheet, and Appendix B would require calculation of some of the intermediate values by fuel type.

APPENDIX A: TASK 2 MEMO

TO: WRUCC PAC
FROM: EDR Group
DATE: April 27, 2017
RE: Proposed Urban-Mixed-Rural Classification Scheme

This classification scheme is based on the rural-urban commuting area (RUCA) codes developed by the Economic Research Service (ERS) of the United States Department of Agriculture. The RUCA codes are calculated at the census tract level based on the 2010 decennial census and 2006-2010 American Community Survey (ACS). The primary codes designate 10 different categories of census tracts based on commuting patterns using ACS Journey-to-Work data. The RUCA codes also utilize the urban area classifications developed from the 2010 decennial census. Because the urban area classifications do not follow census tract boundaries exactly, tracts are considered part of an urban area if at least 30 percent of their population lives inside the urban area boundary when calculated at the census block scale. The primary codes can be seen in Table A-25.

Table A-25. The 10 Primary RUCA Codes

Code	Description
1	Metropolitan area core: primary flow within an urbanized area (UA)
2	Metropolitan area high commuting: primary flow 30% or more to a UA
3	Metropolitan area low commuting: primary flow 10% to 30% to a UA
4	Micropolitan area core: primary flow within an Urban Cluster of 10,000 to 49,999 (large UC)
5	Micropolitan high commuting: primary flow 30% or more to a large UC
6	Micropolitan low commuting: primary flow 10% to 30% to a large UC
7	Small town core: primary flow within an Urban Cluster of 2,500 to 9,999 (small UC)
8	Small town high commuting: primary flow 30% or more to a small UC
9	Small town low commuting: primary flow 10% to 30% to a small UC
10	Rural areas: primary flow to a tract outside a UA or UC

The census tract based designations provide a system similar to the core-based statistical area (CBSA) designations of counties that the Census Bureau defines based on commuter-flows. However, the RUCA codes offer considerably greater granularity and flexibility to investigate urban-rural differences within some of the eight participating states larger counties. The 10 primary codes also allow significant flexibility in classifying counties as urban, mixed, or rural. Based on county-level CBSA designations, identifying mixed counties in a meaningful way would be especially difficult. Our adopted aggregation scheme is presented in Table A-26. This classification scheme has also been deployed in the attached map showing the urban, mixed, and rural census tracts for all eight states.

Table A-26. Adopted Aggregation to Urban-Mixed-Rural Classes with Summary Statistics for the Eight-State Region

UMR Classification	RUCA Codes Included	Count of Census Tracts	Total Land Area (sq.mi.)	Total Population
Urban	1, 4	12203	83,595	56,628,426
Mixed	2, 3, 5	1122	187,366	4,776,604
Rural	6, 7, 8, 9, 10	926	574,841	3,146,635

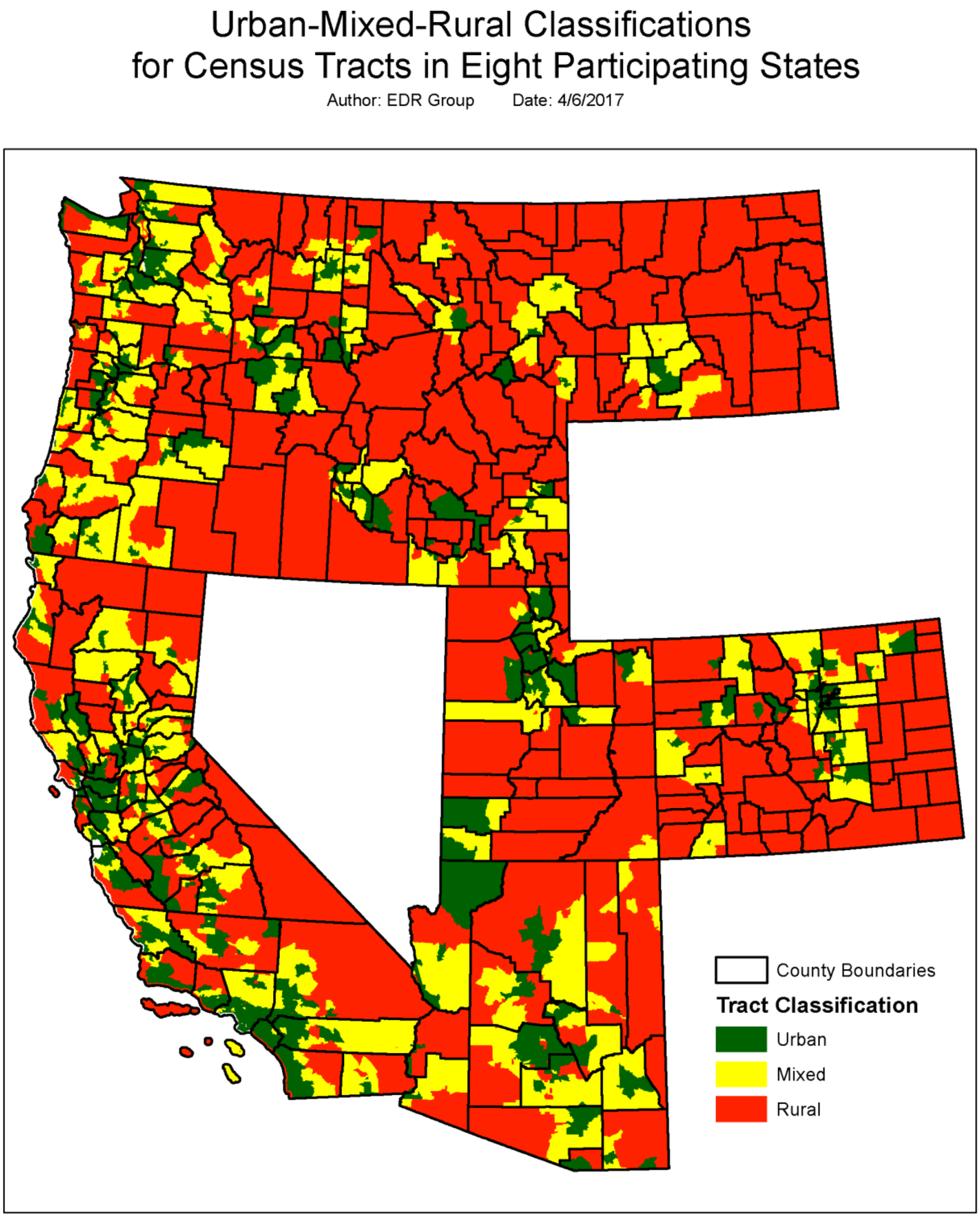
The urban classification (RUCA codes 1 and 4) includes all census tracts were the primary commuting flow suggests that the majority of residences and workplaces are within census-designated urban areas. Using the statistics presented in Table A-26, we see that the average population density for the urban tracts is 677 people per square mile. This classification includes those who live in dense urbanized areas and those that live in smaller urban clusters but commute within the cluster's boundaries. Some census tracks on the urban fridge are also captured.

The mixed classification (RUCA Codes 2,3, and 5) captures census tracts that are not within urban areas but where significant portions of people commute to urban areas: at least 10 percent commute to areas with over 50,000 population or 30 percent commute to areas with over 10,000 residents. These tracts are much less dense, with only 25 people per square mile on average. These tracts are likely much more suburban, and in many cases even stretch out from population centers to include land with more rural settlement and land use patterns.

Rural areas (RUCA codes 6, 7, 8, 9, and 10) are classified as those tracts in which less than 30 percent of commuters go to areas with more than 10,000 residents and hardly any commute to larger urban areas. The average density of these tracts in just under 5.5 people per square mile. Residents of these tracts are likely to have to drive further to reach amenities than they drive for their daily commutes.

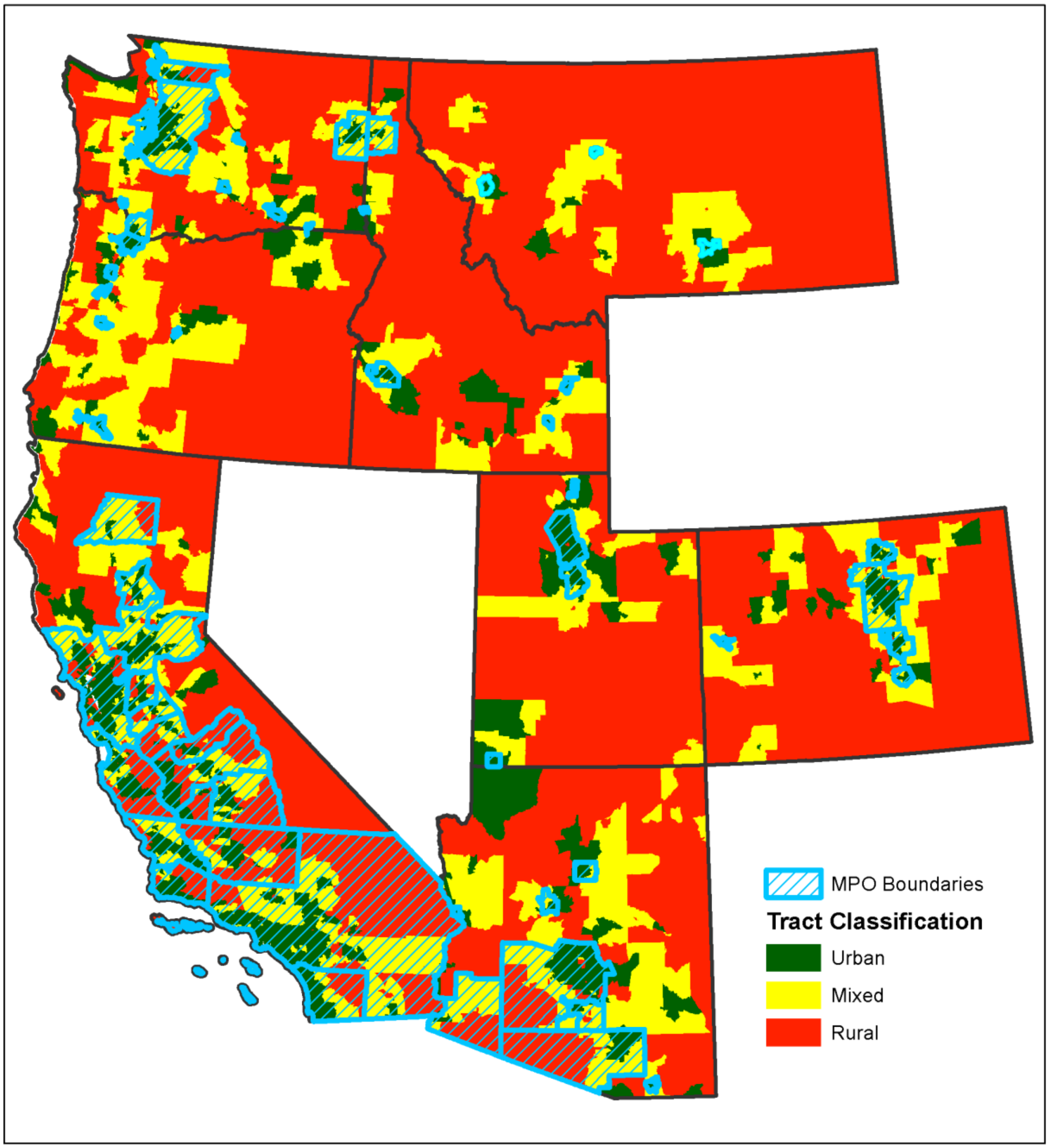
Examining this data at only the county level would prevent separating out the densely-populated portions of counties from portions of counties that are sometimes dozens of miles removed, where there is relative limited economic attachment to the urban area. In the attached map, many counties can be identified that contain urban, mixed, and rural census tracts. Classifying these counties entirely as mixed would obscure a great deal of useful detail and variation.

Based on these findings and categorization system, using existing data and the methodology developed by the Bureau of Transportation Statistics for the National Household Transportation Survey (NHTS) Transferability Statistics, when state-specific information is not available, we were able to develop a VMT estimation at the census tract level that is better than aggregate county-level estimates. Using both VMT and fuel use at the census tract level and aggregating them to the country level for final reporting purposes (and possibly tool development should that be initiated later in the study), was both feasible and a preferred approach to maintain the character of travel developed using these classification methods.


Urban-Mixed-Rural Classifications
for Census Tracts in Eight Participating States
Author: EDR Group Date: 4/6/2017
County Boundaries
Tract Classification
Urban
Mixed
Rural

Urban-Mixed-Rural Classifications
for Census Tracts in Eight Participating States

Author: EDR Group   Date: 4/6/2017



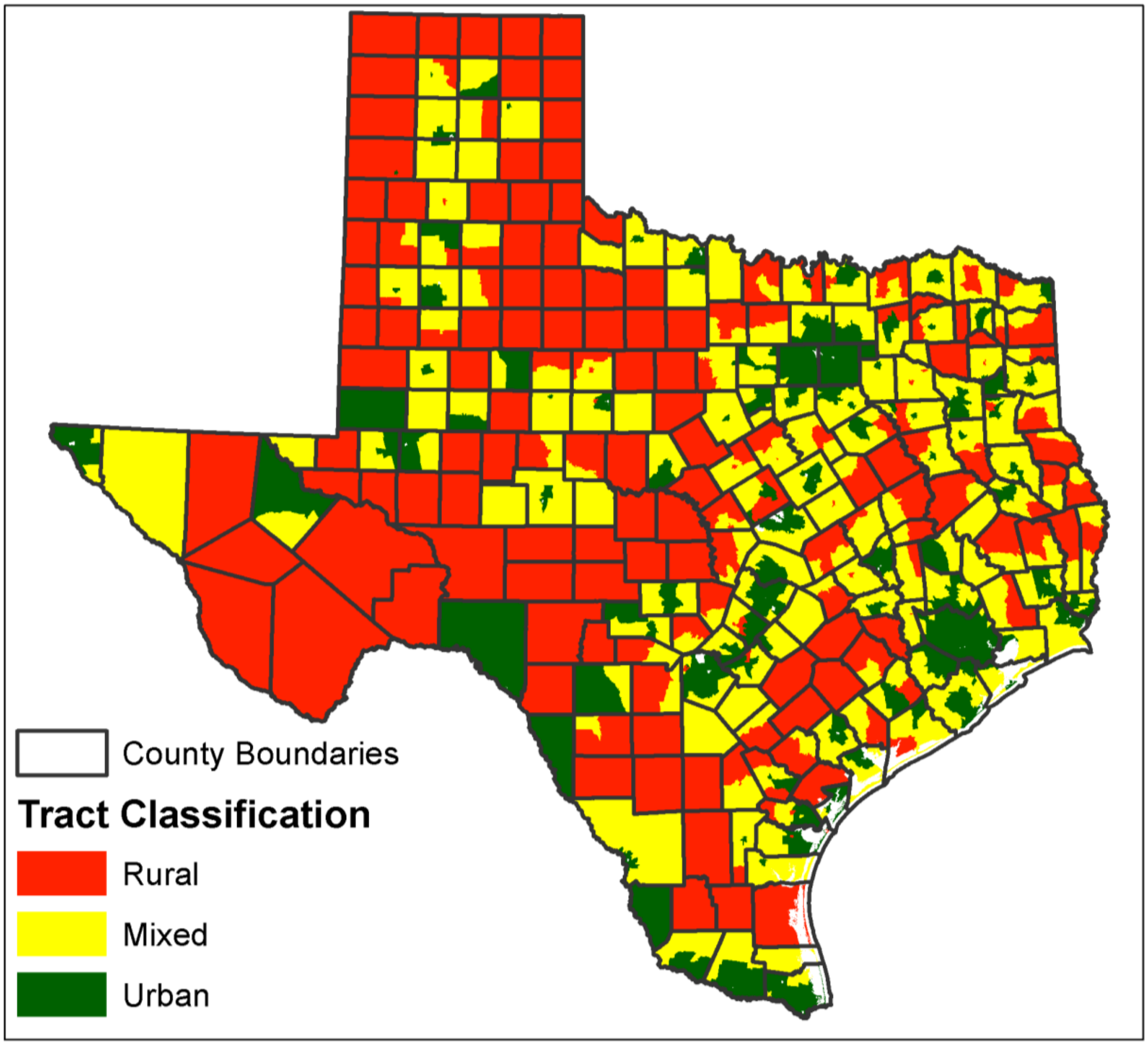
ADDENDUM TO TASK 2 MEMO

Addition of Texas tract level classification data.

Urban-Mixed-Rural Classifications for Census Tracts in Texas

Author: EDR Group Date: 4/6/2017

Tracts classified based on the Urban-Rural Commuting Area codes assigned by the Department of Agriculture's Economic Research Service.
Ten primary codes consolidated to Urban-Mixed-Rural classes using the methodology developed by EDR Group for the RUC West Urban-Rural Financial Impacts study.



Appendix B: Percentage of Annual Vehicle Miles Traveled by Fuel Type

Figure B-1. Map of Gas VMT

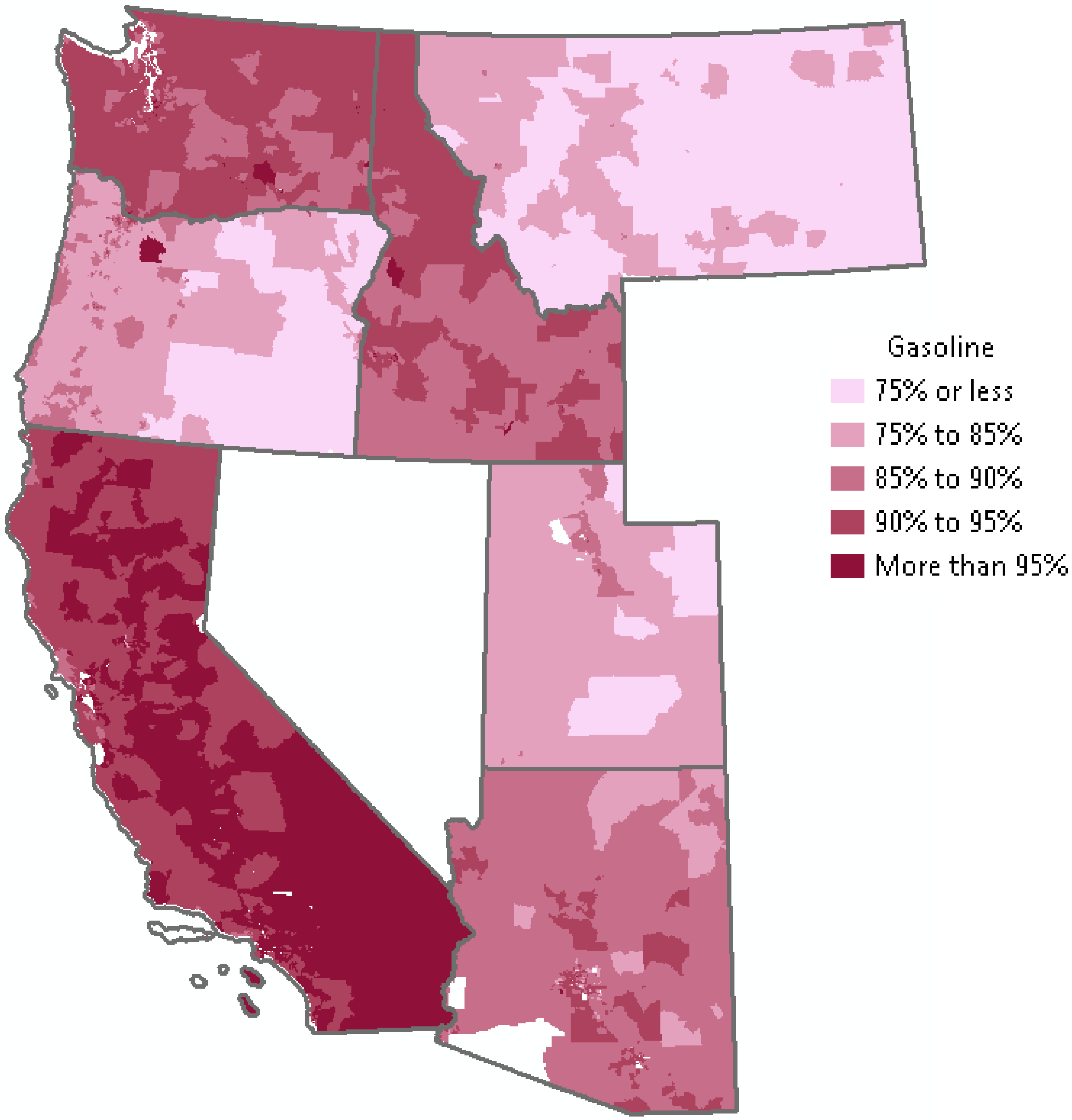


Figure B-2. Map of Non-gas VMT

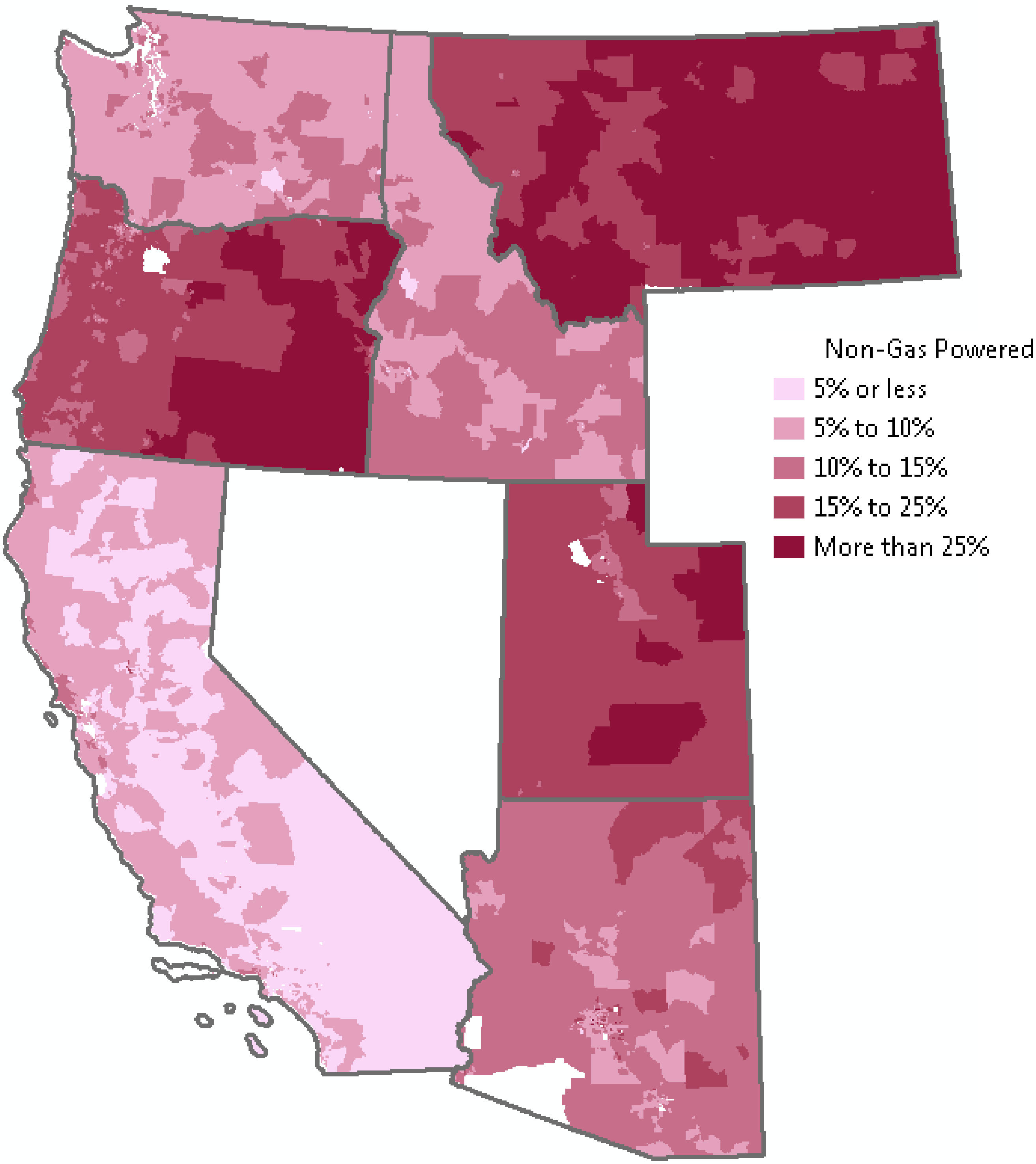


Figure B-3. Map of Electric & H2 VMT

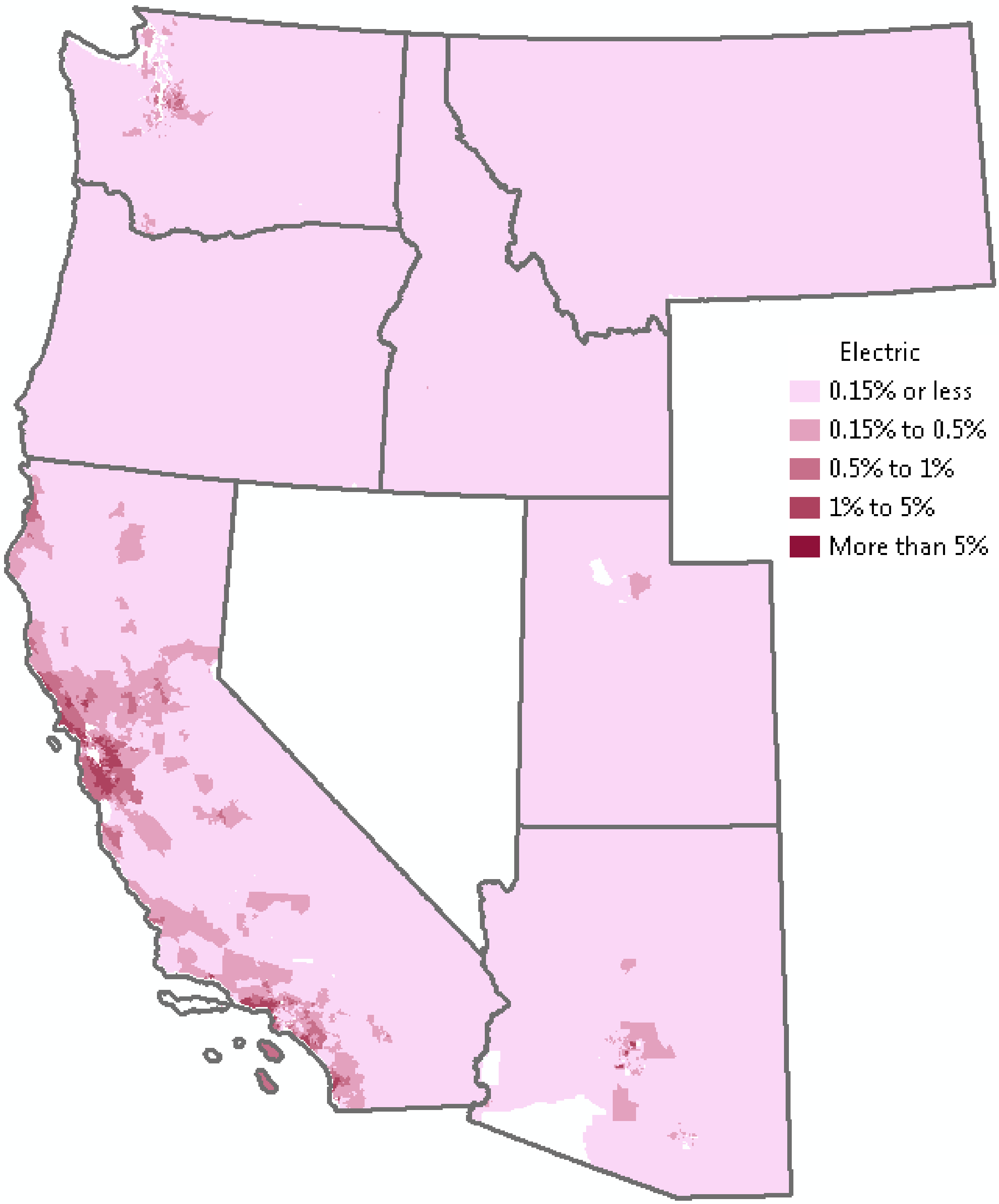


Figure B-4. Map of Flex Fuel VMT

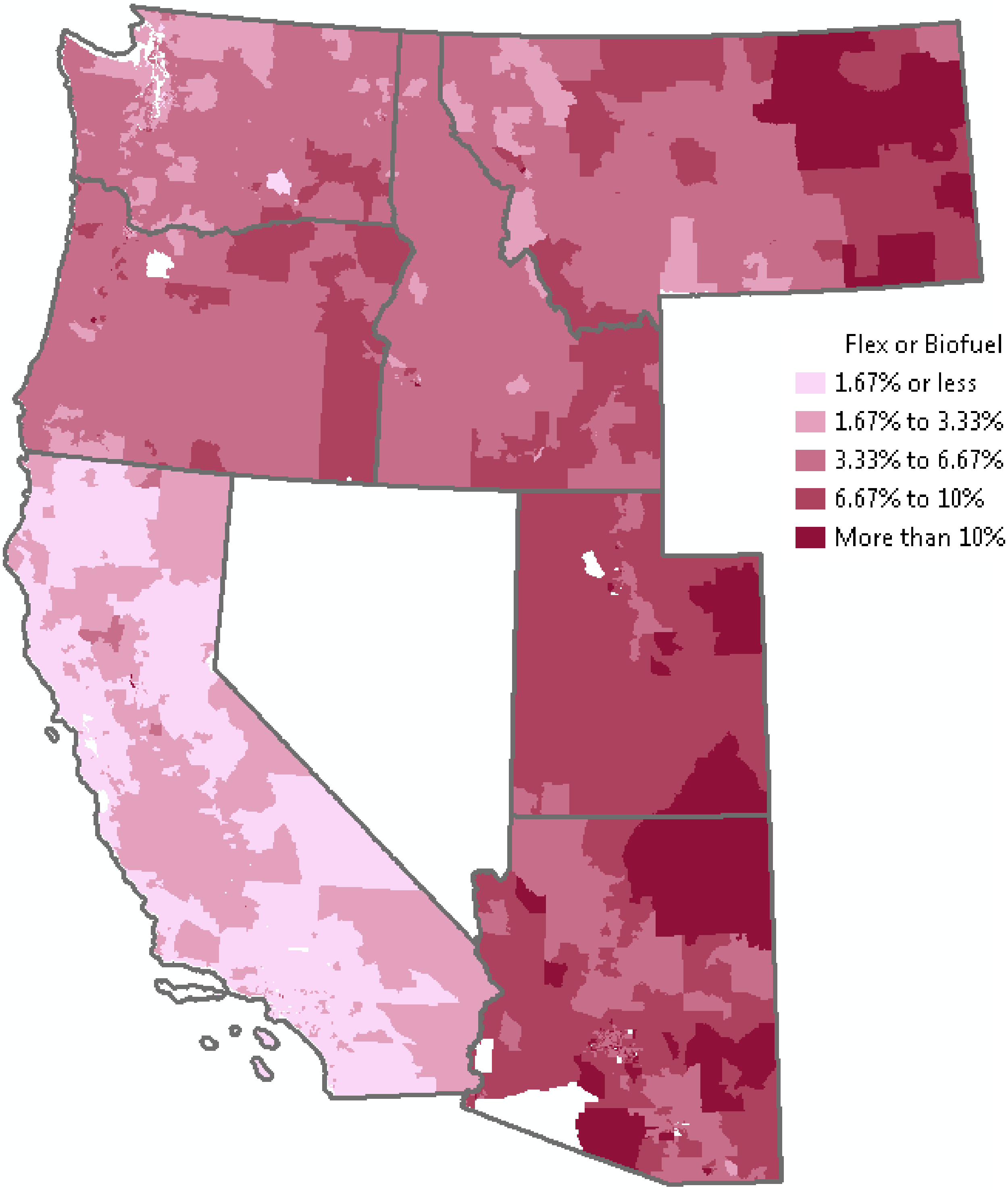


Figure B-5. Map of Hybrid VMT

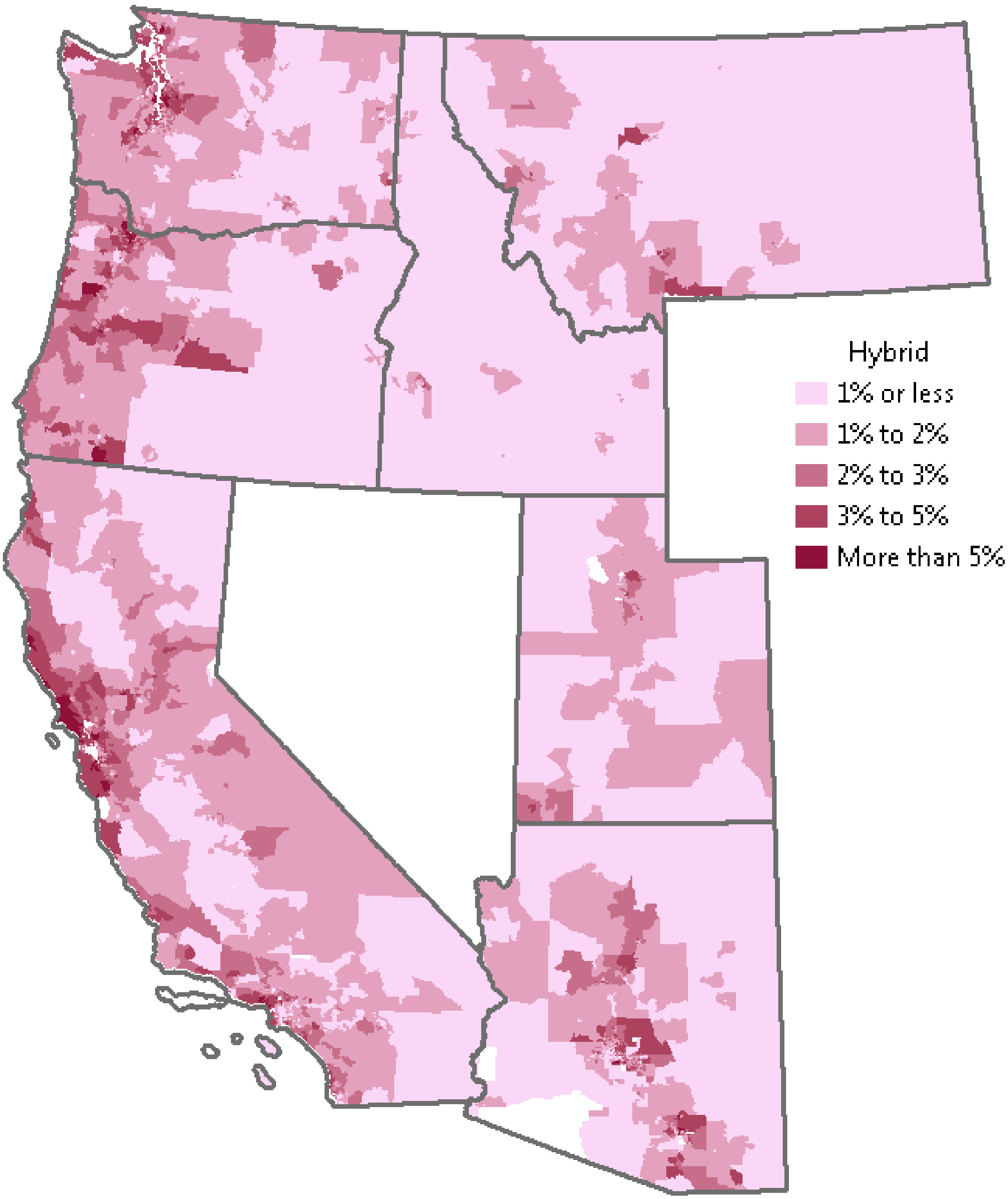


Figure B-6. Map of Fossil Fuels VMT

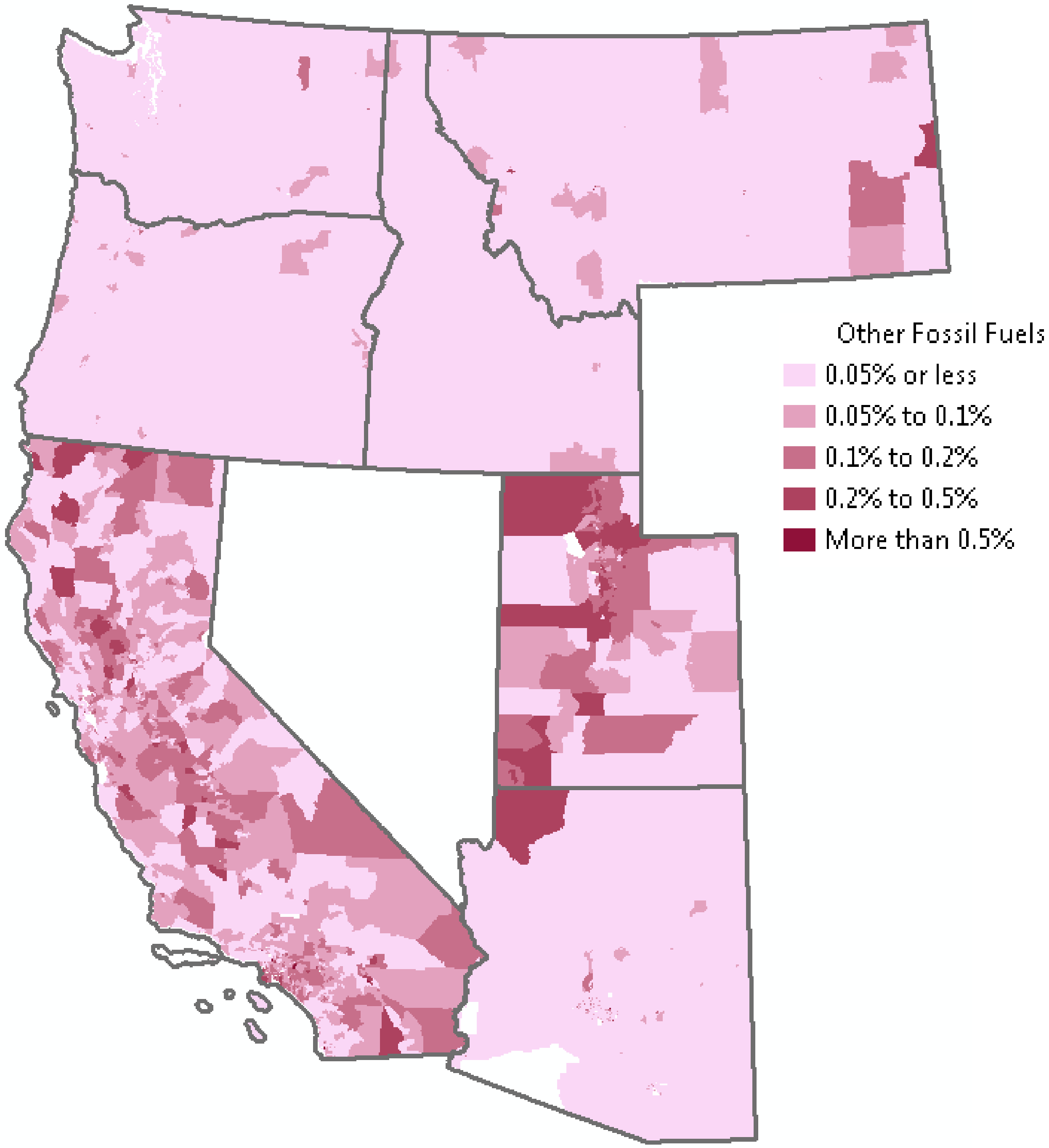


Figure B-7. Map of Diesel VMT

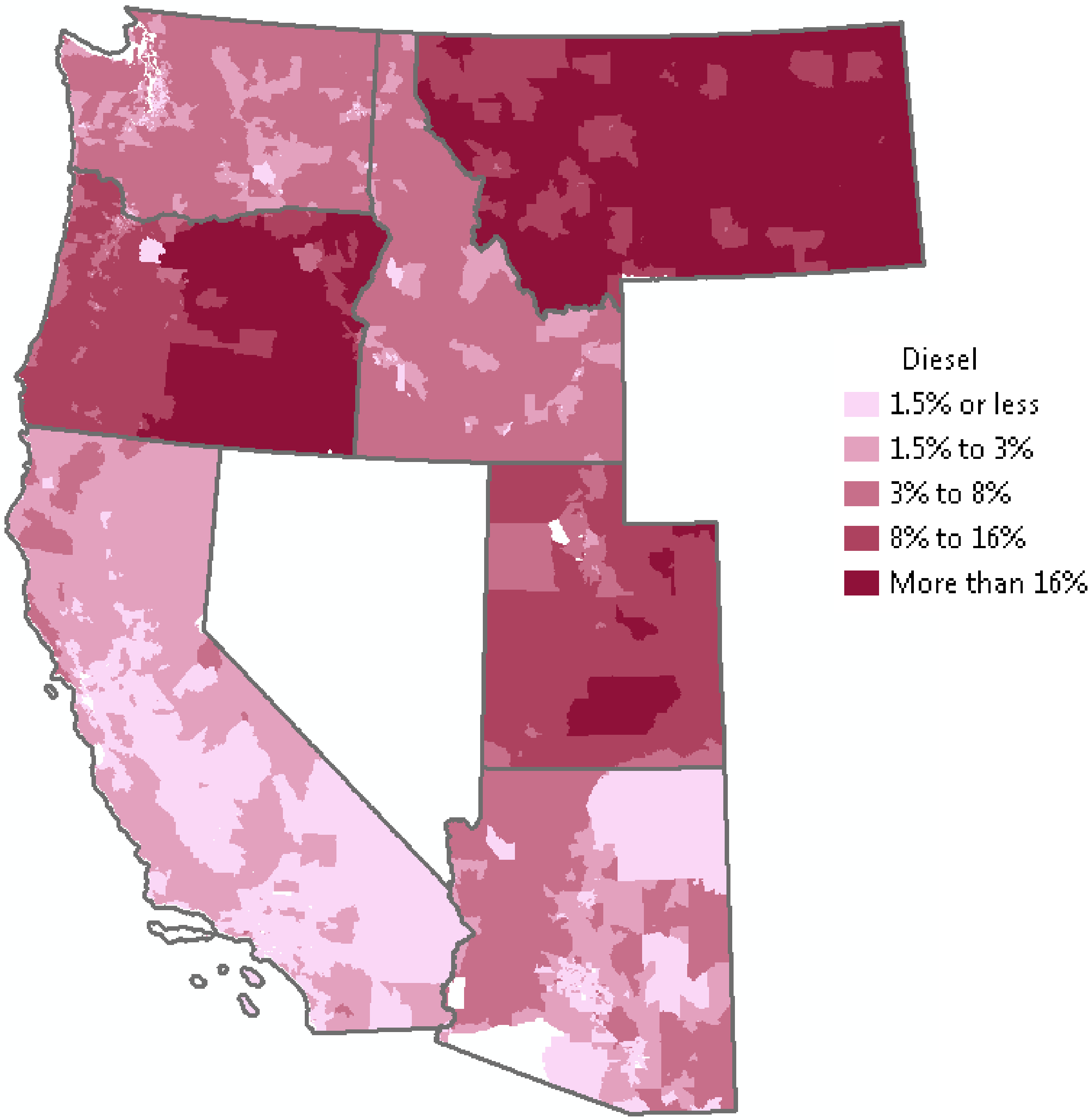


Figure B-8. Texas Gasoline VMT

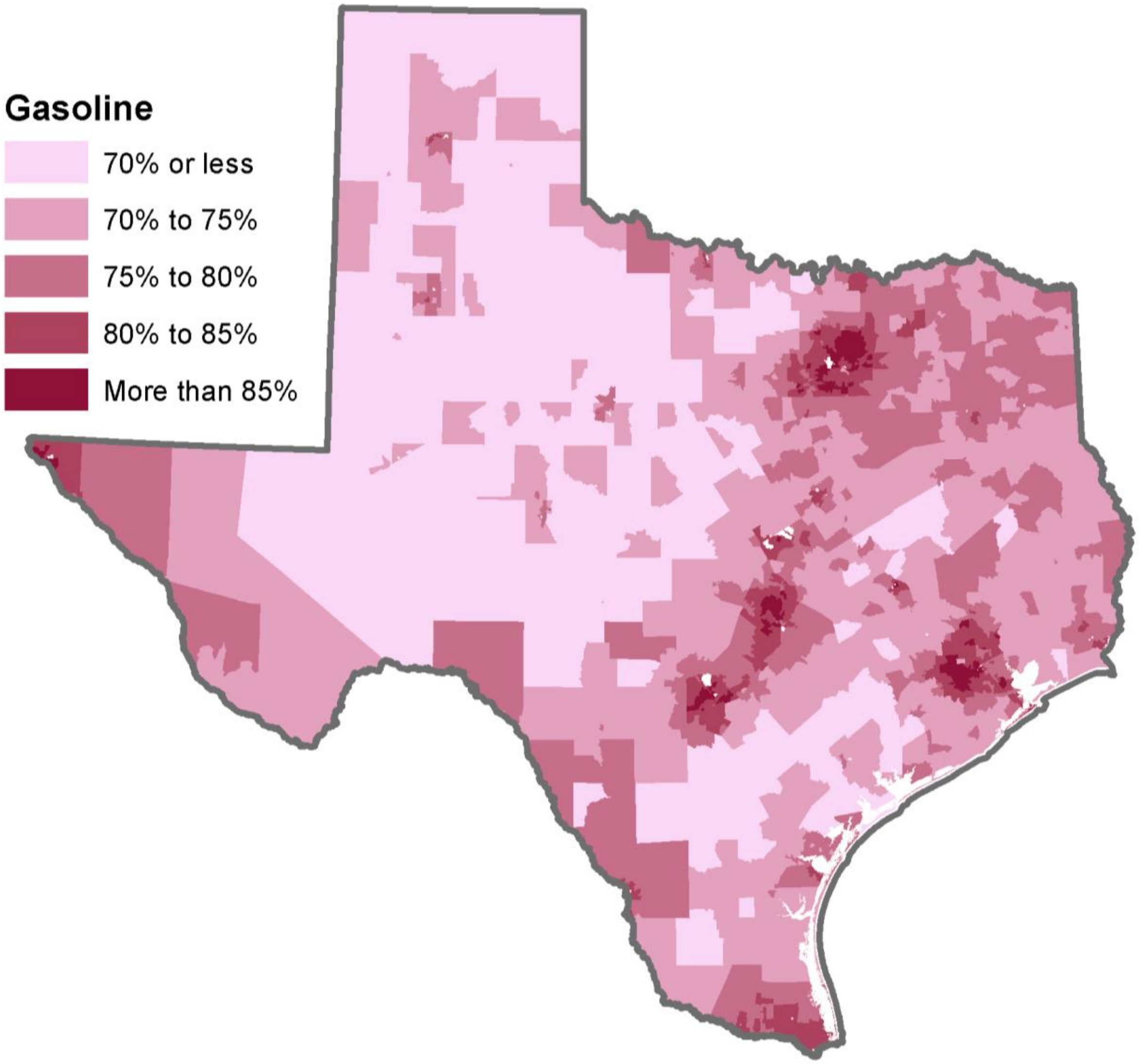


Figure B-9. Texas Non-Gas-Powered VMT

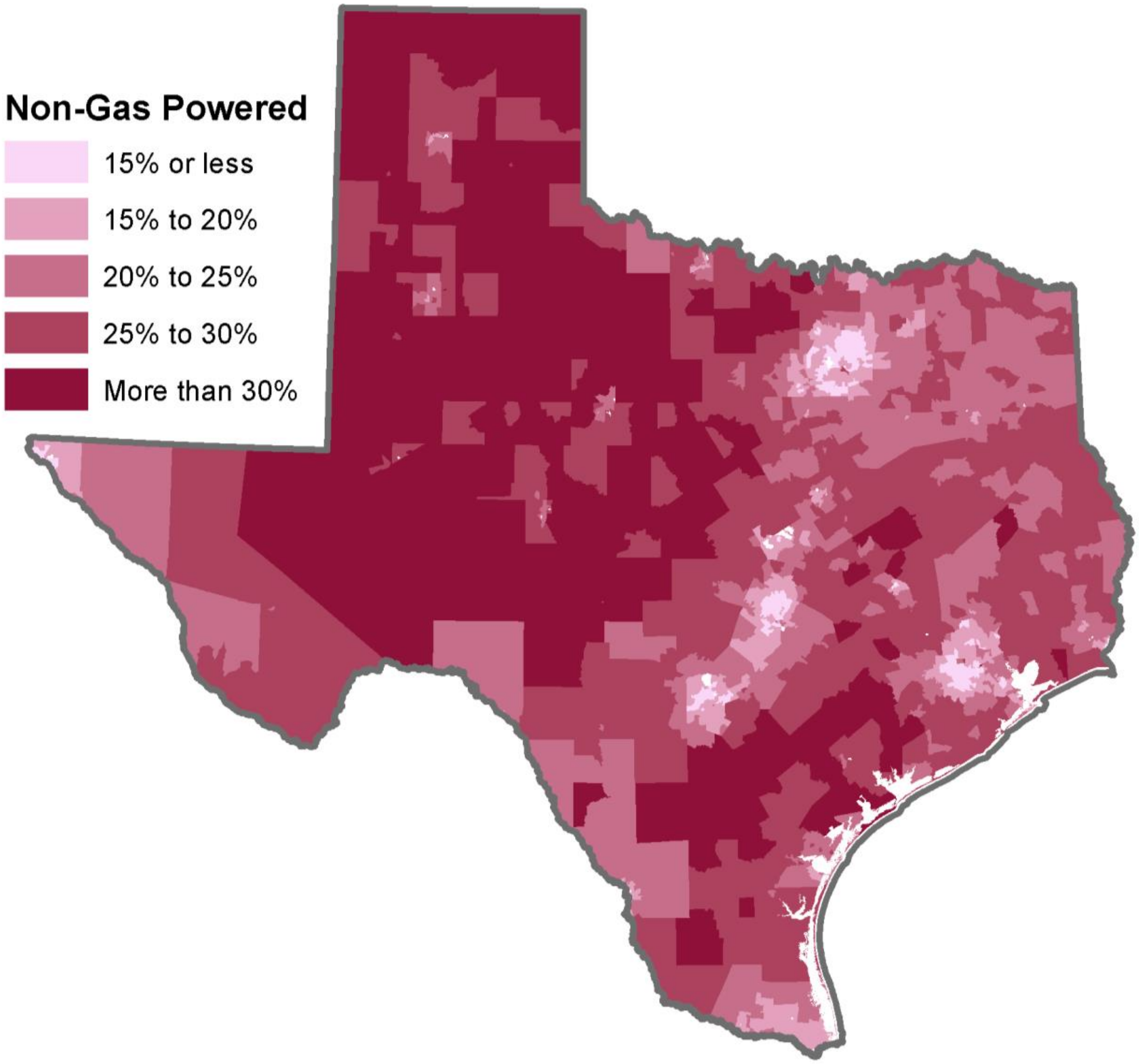


Figure B-10 Texas Electric and Hydrogen VMT

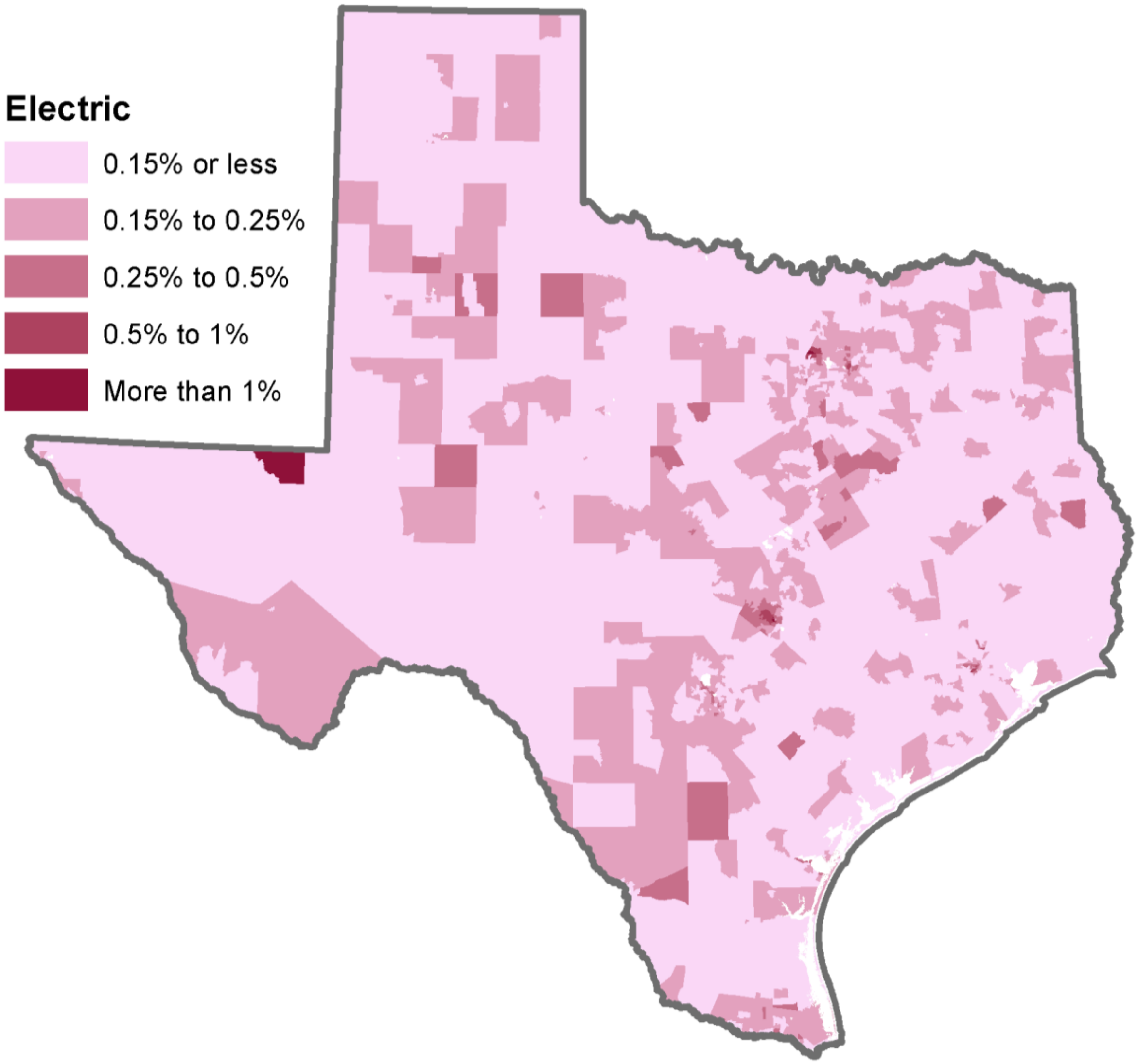


Figure B-11 Texas Flex fuel and Biofuel VMT

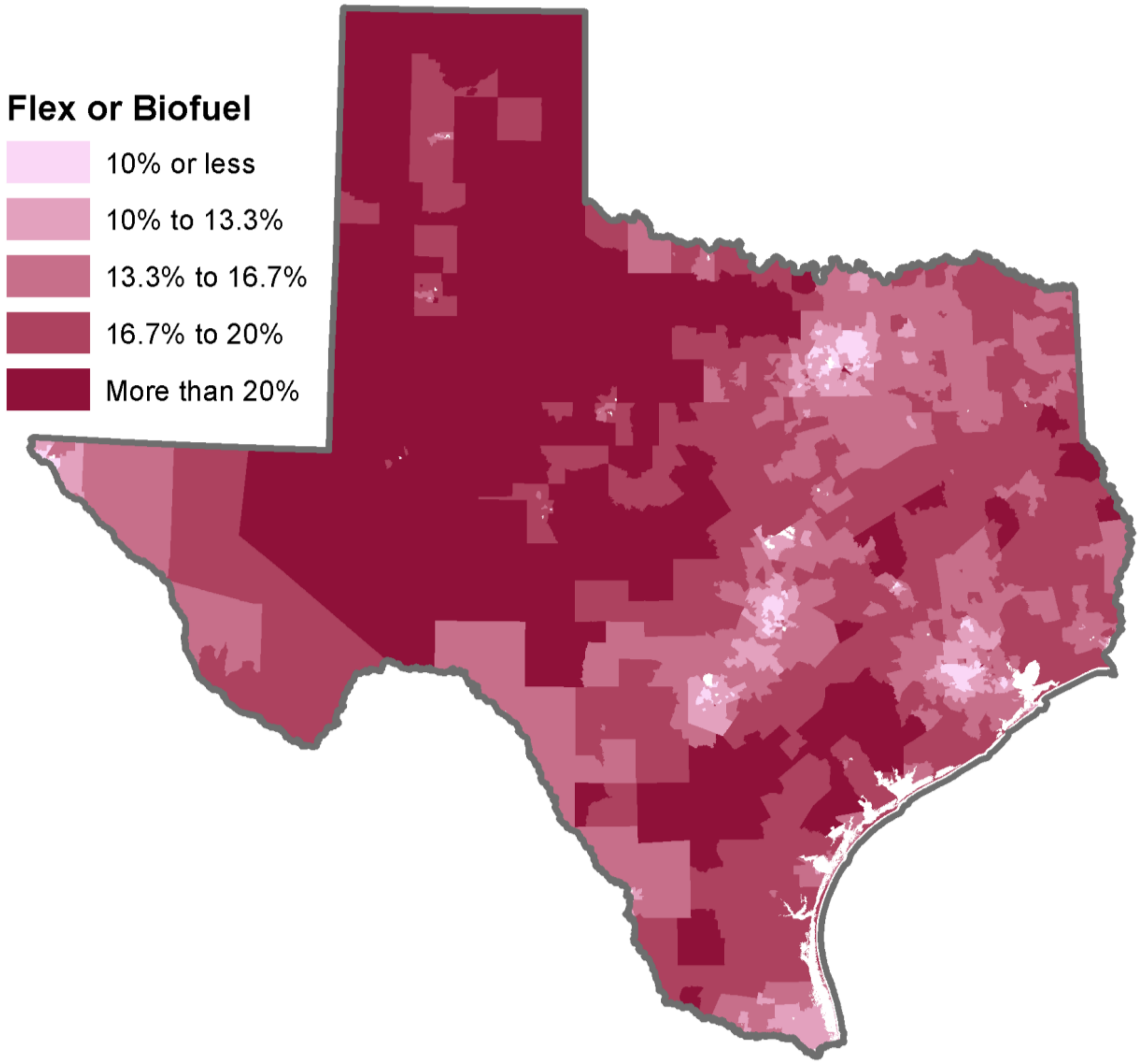


Figure B-12 Texas Hybrid VMT

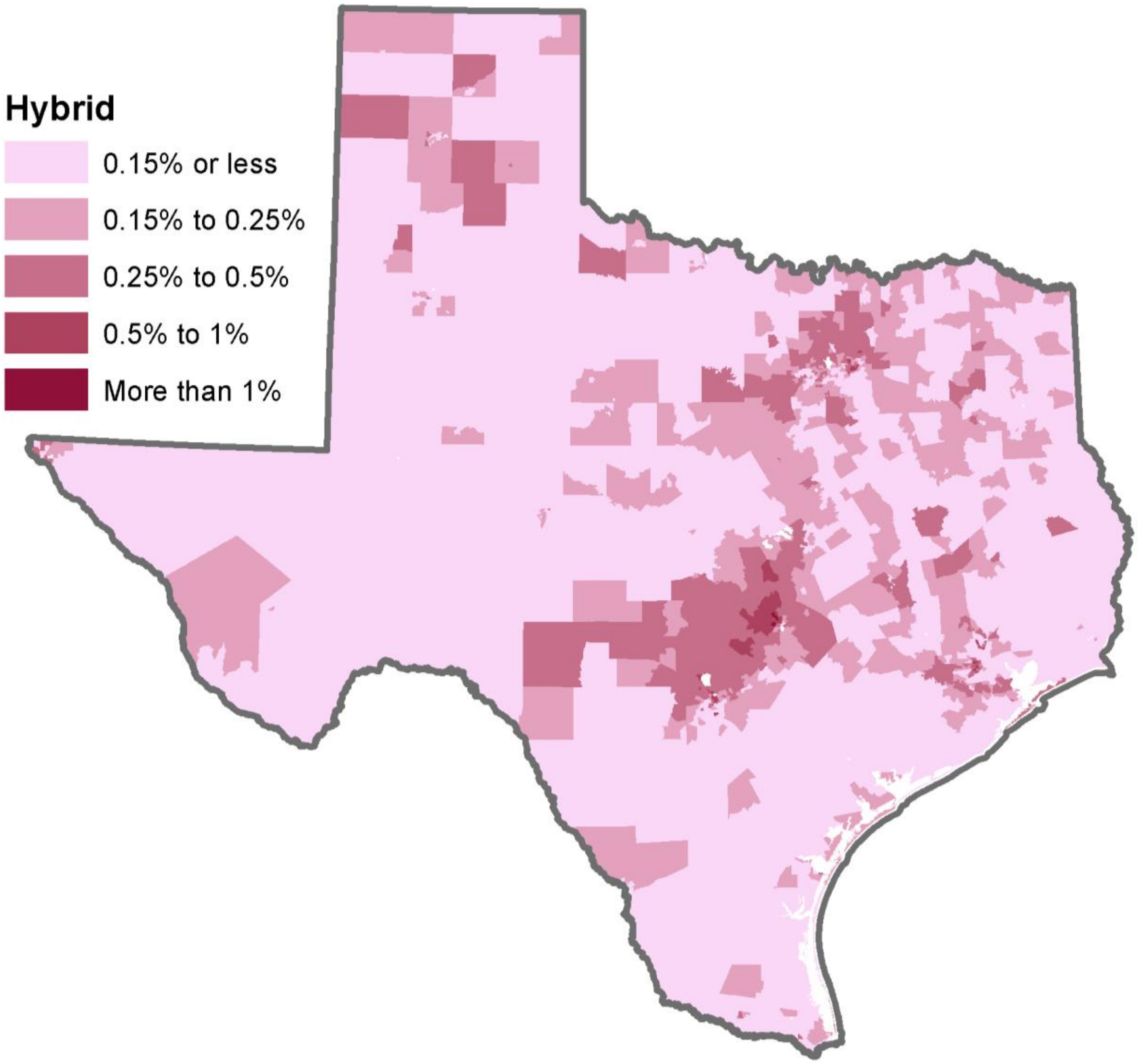


Figure B-13 Texas VMT from Other Fossil Fuels

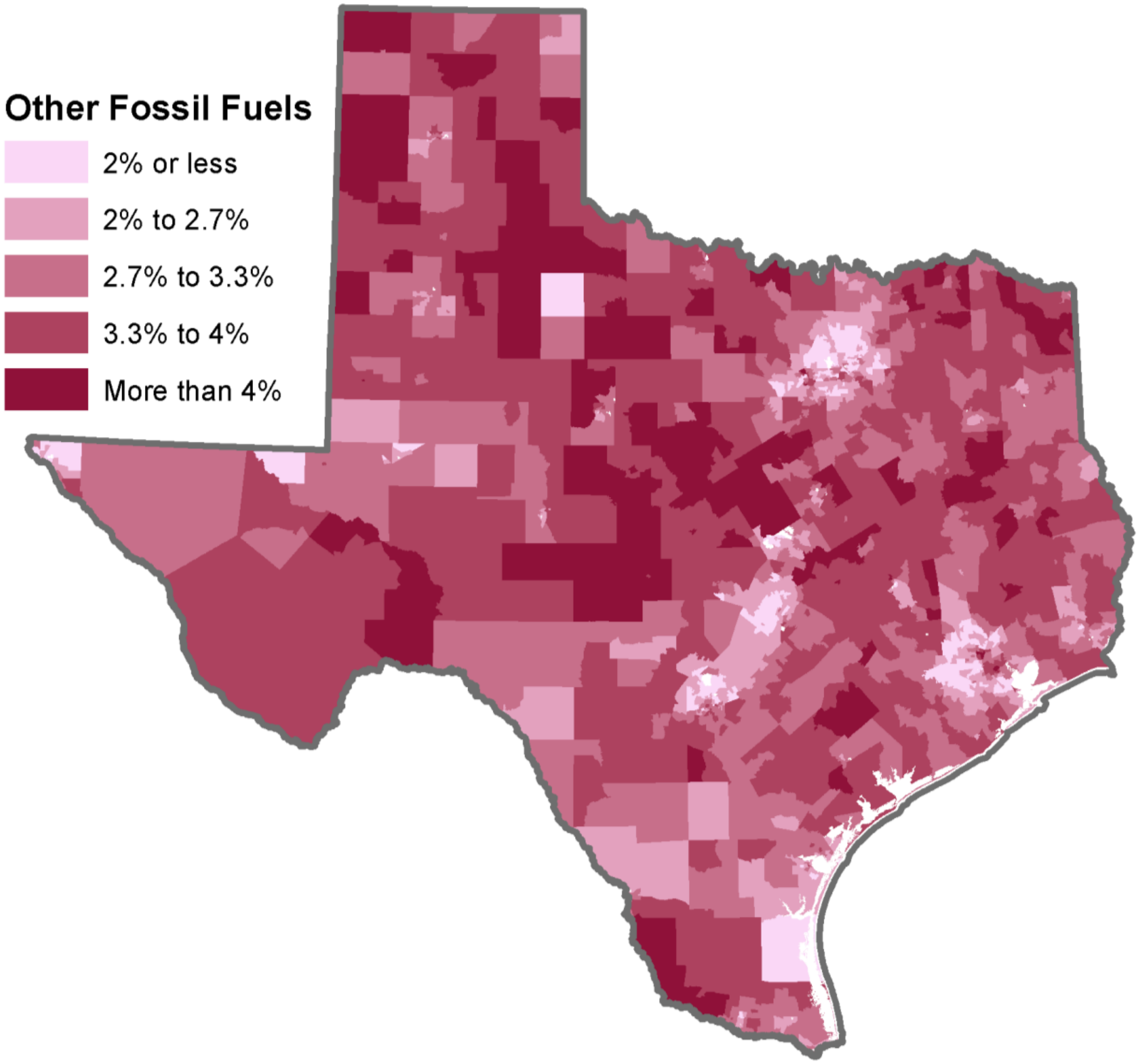
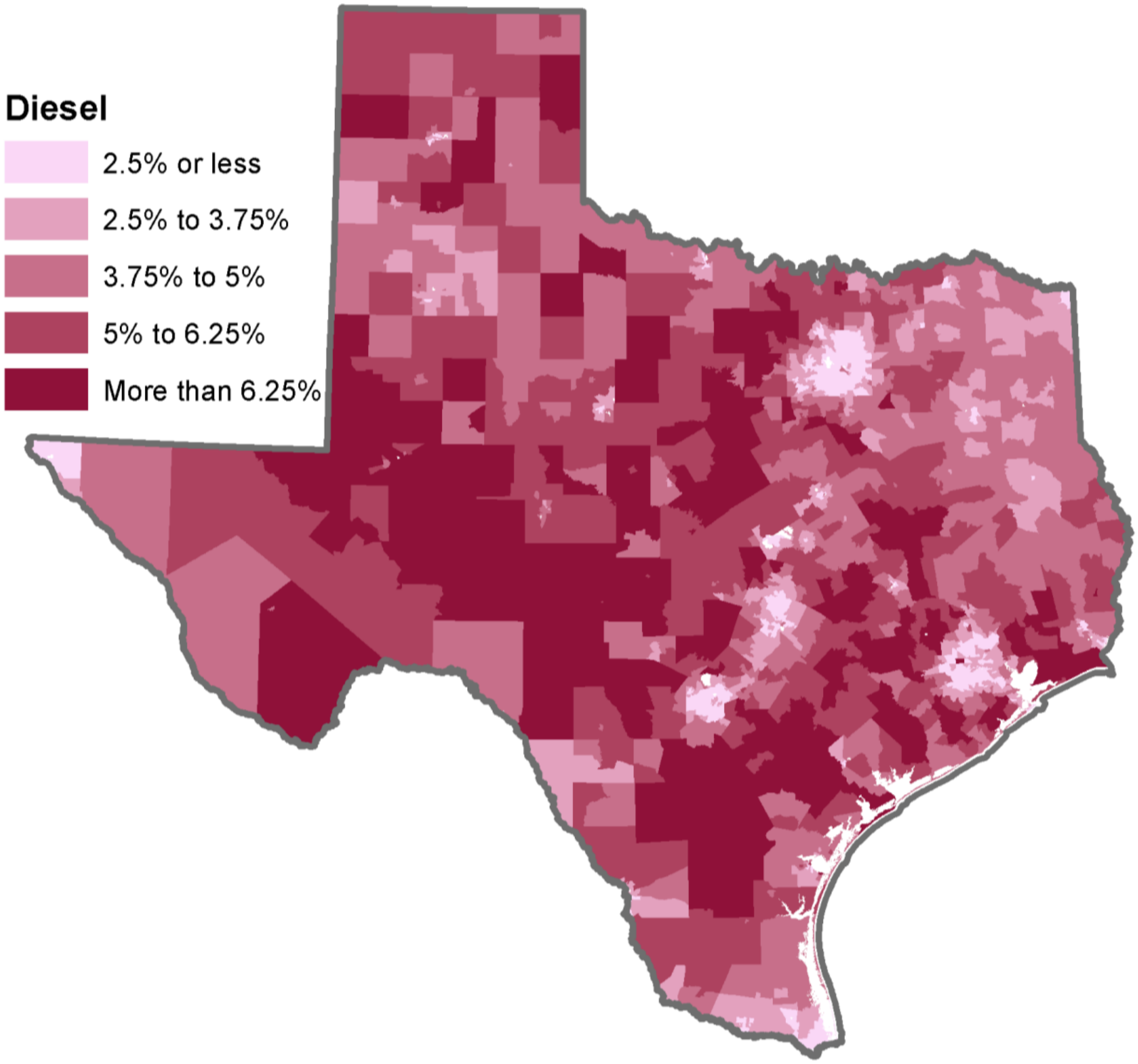


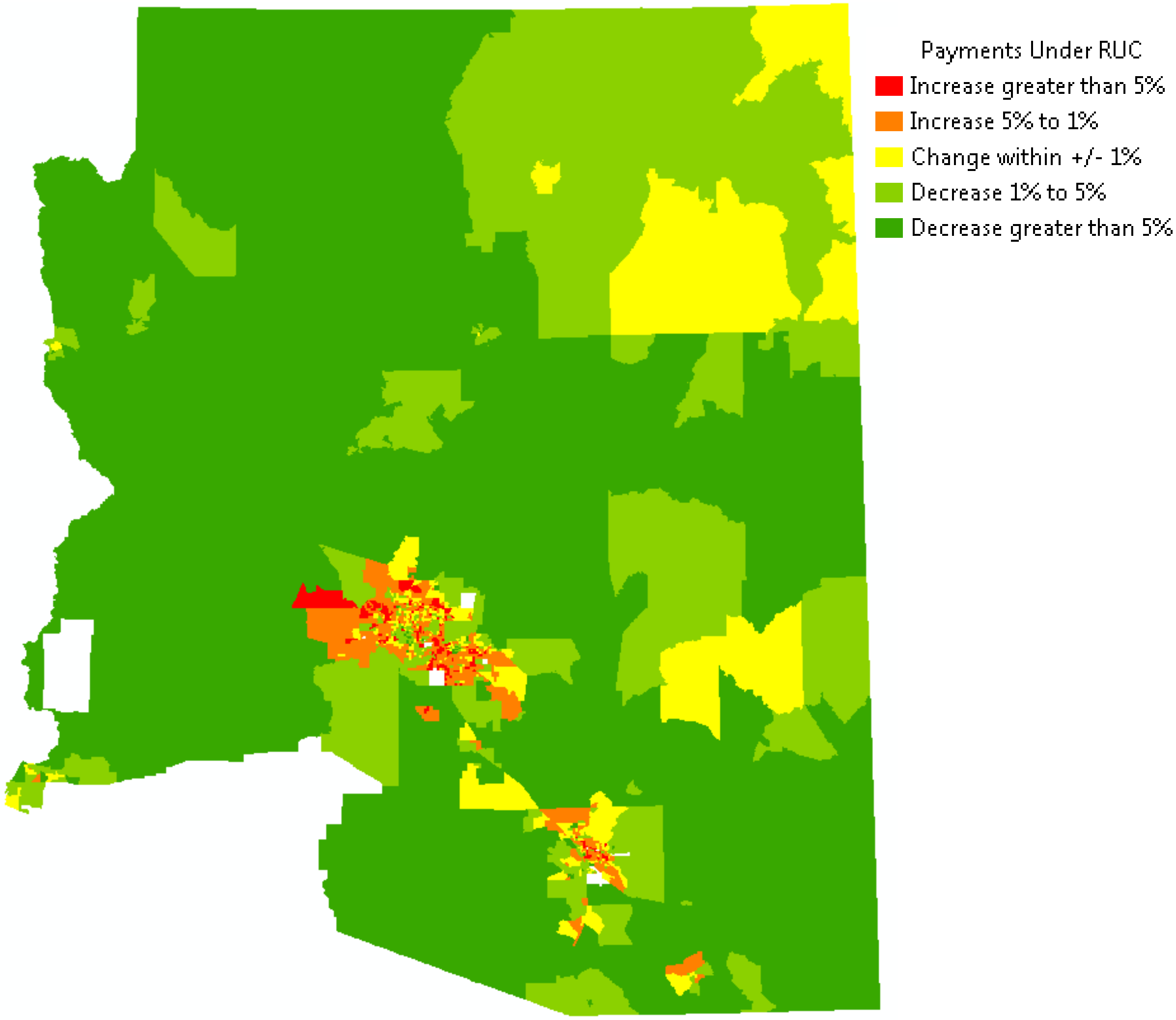
Figure B-14 Texas Diesel VMT



Appendix C: Changes in Household Costs Under a Revenue Neutral RUC

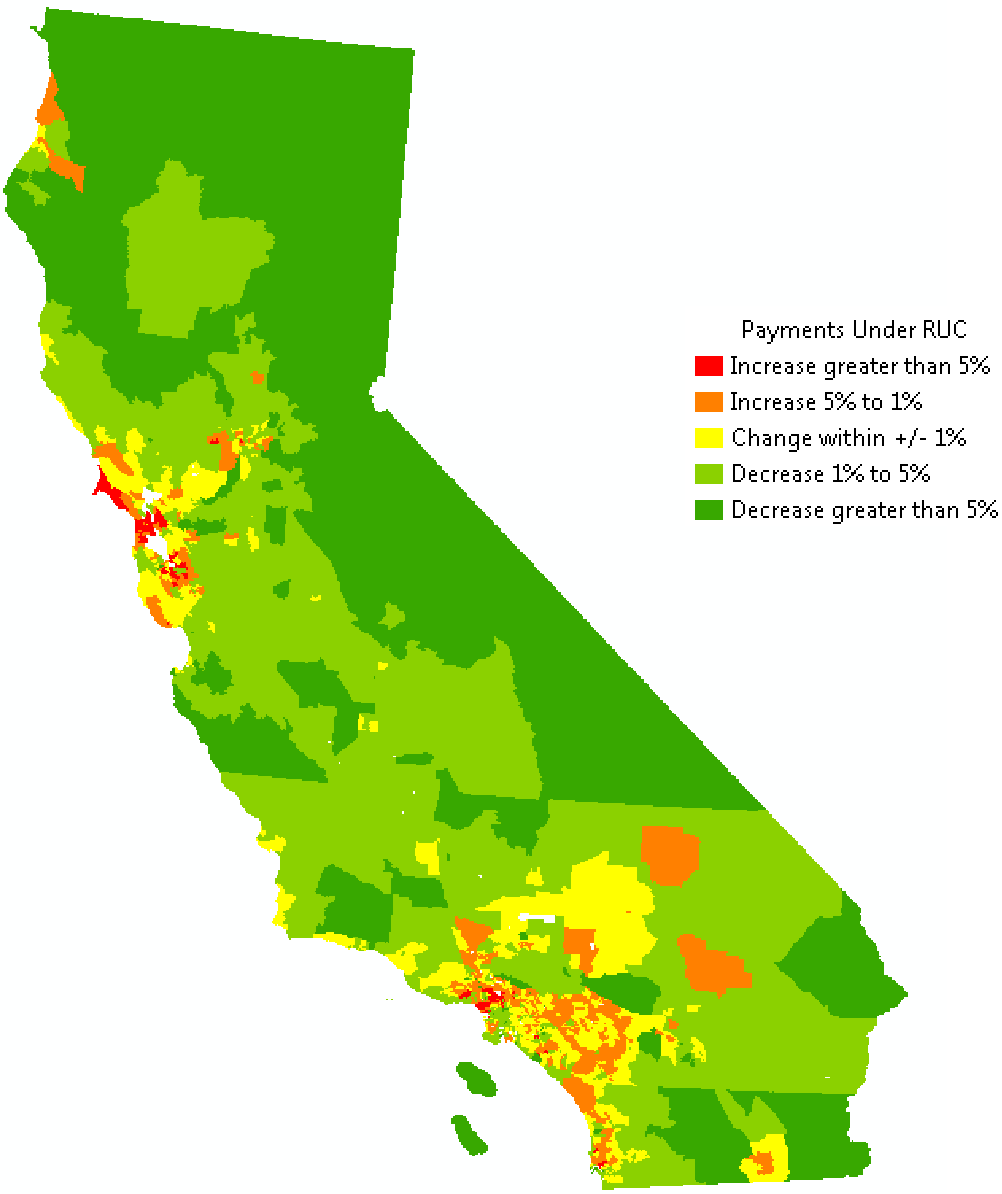
Arizona

In Arizona, increases in payments are concentrated around the Phoenix and Tucson metro areas. However, some urban tracts in the Phoenix area may pay less under the RUC, just like the rural areas. In the northeast portion of the state, benefits from a RUC are decreased due to high penetration of flex- and biofuel vehicles in that part of the state that will be covered under a RUC, some of which were assumed to not currently pay gasoline tax.



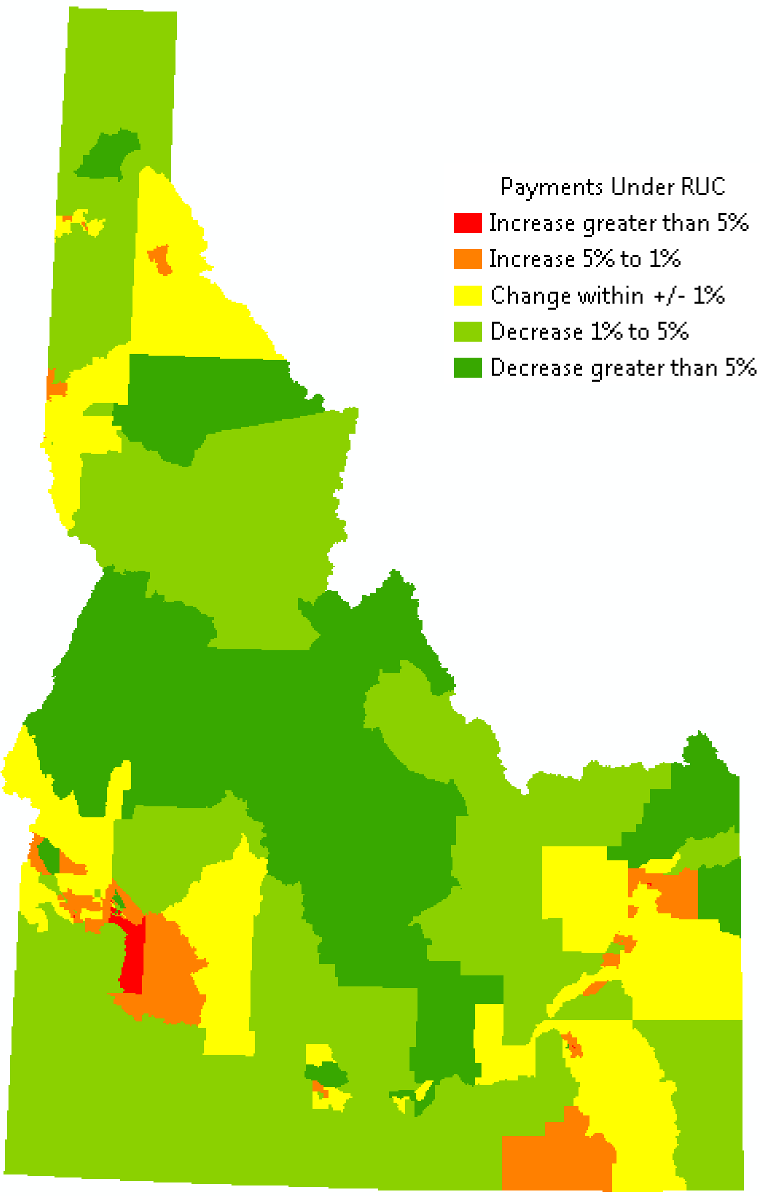
CALIFORNIA

In California, the greatest increases in payments under a RUC are seen in the Bay Area and Los Angeles. As seen in the maps included in Appendix A, there is relatively high portion of hybrid vehicles in these areas, especially around San Francisco, that have above average fuel efficiency and will pay more under a RUC. Additionally, these areas have one of the highest concentrations of electric vehicles of all the participating states, which are currently not contributing to the fuel tax but will be subject to a RUC. Excluding high VMT mixed tracts in the Los Angeles region, most of inland California households will pay less under a RUC. A few smaller cities with tracts seeing little change in either direction can be seen in the Central Valley and along the coast.



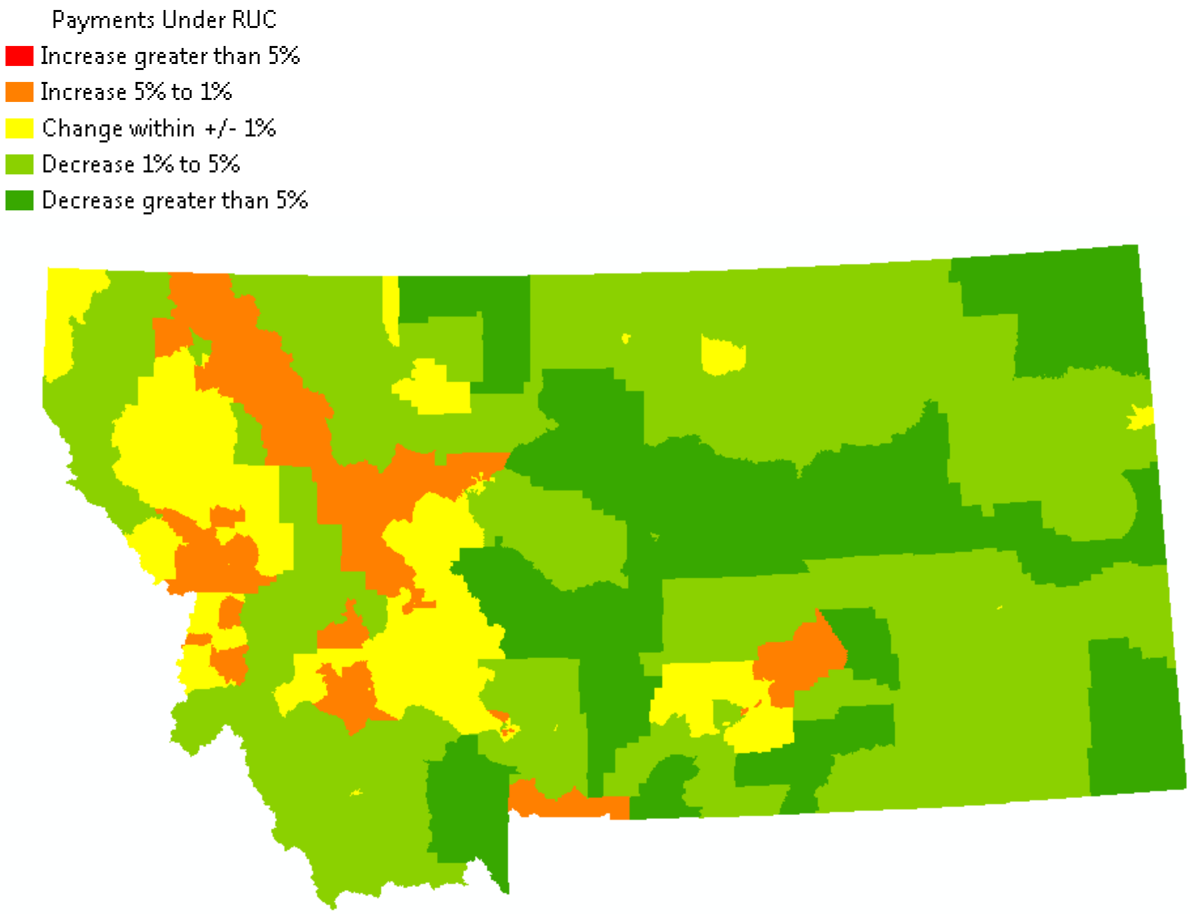
IDAHO

In Idaho, the limited number of tracts estimated to pay more than 5 percent greater fees under a RUC are located in the densest areas of cities like Boise, Idaho Falls and Pocatello. Households in these tracts are estimated to have lower VMT per year than most other parts of Idaho. Payments under a RUC for mixed and rural areas in Idaho are relatively diffuse, with many areas seeing below a 5 percent decrease in costs compared to what they are now paying under a gas tax.



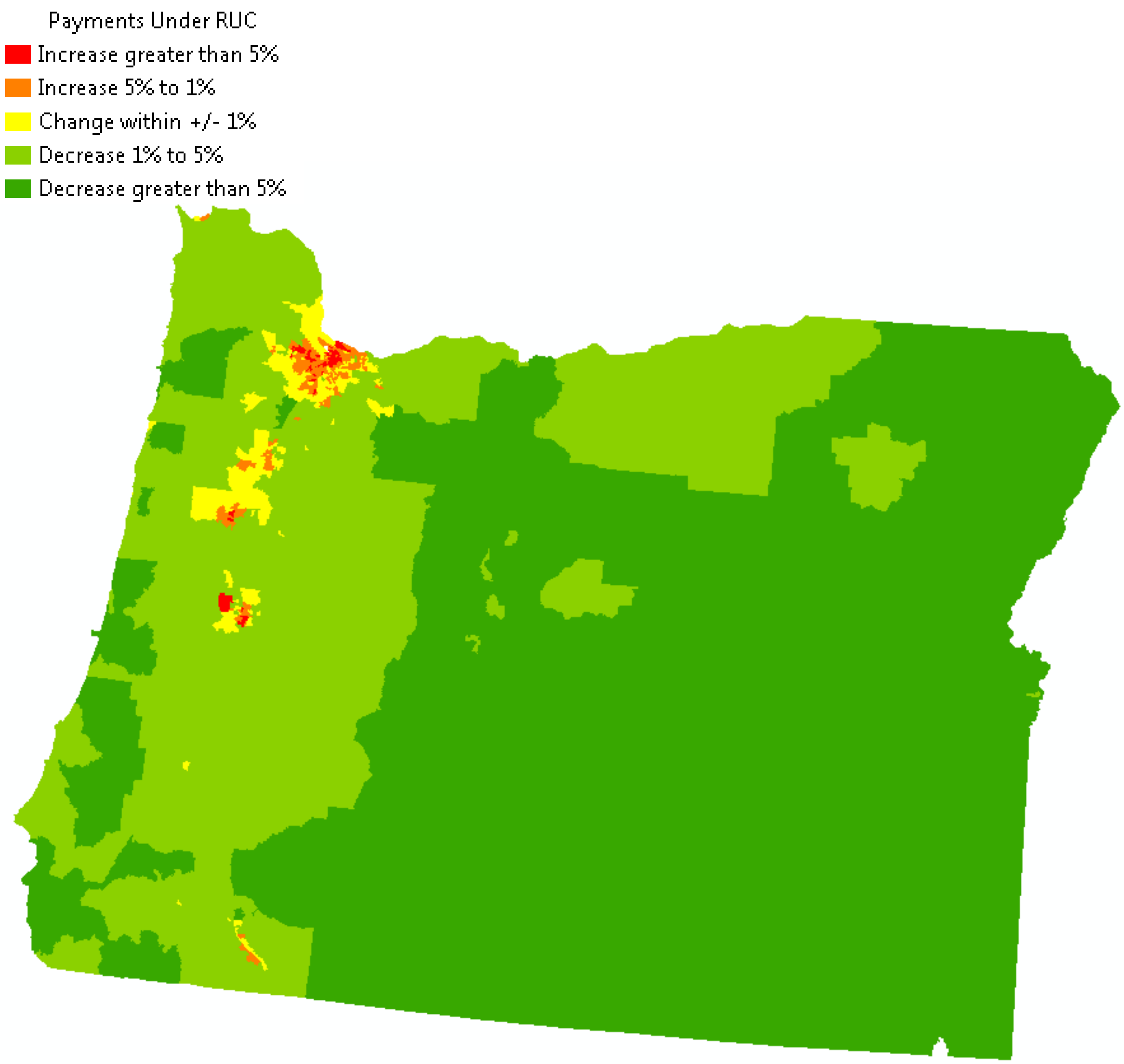
MONTANA

Montana is the only state where no tracts see an increase in payments greater than 5 percent of the level they are estimated to currently pay under the gas tax. Many of the households in tracts that are expected to experience increases are large tracts containing households with high estimated VMT. Because of the large size of tracts (due to low population densities in much of the state) and small variation across the state, a tract only needs to have slightly higher VMT, slightly more flex- or biofuel use, or slightly better average fuel efficiency to pay more under the RUC. Because many vehicles are diesel-powered and external to this analysis, tracts are even more sensitive.



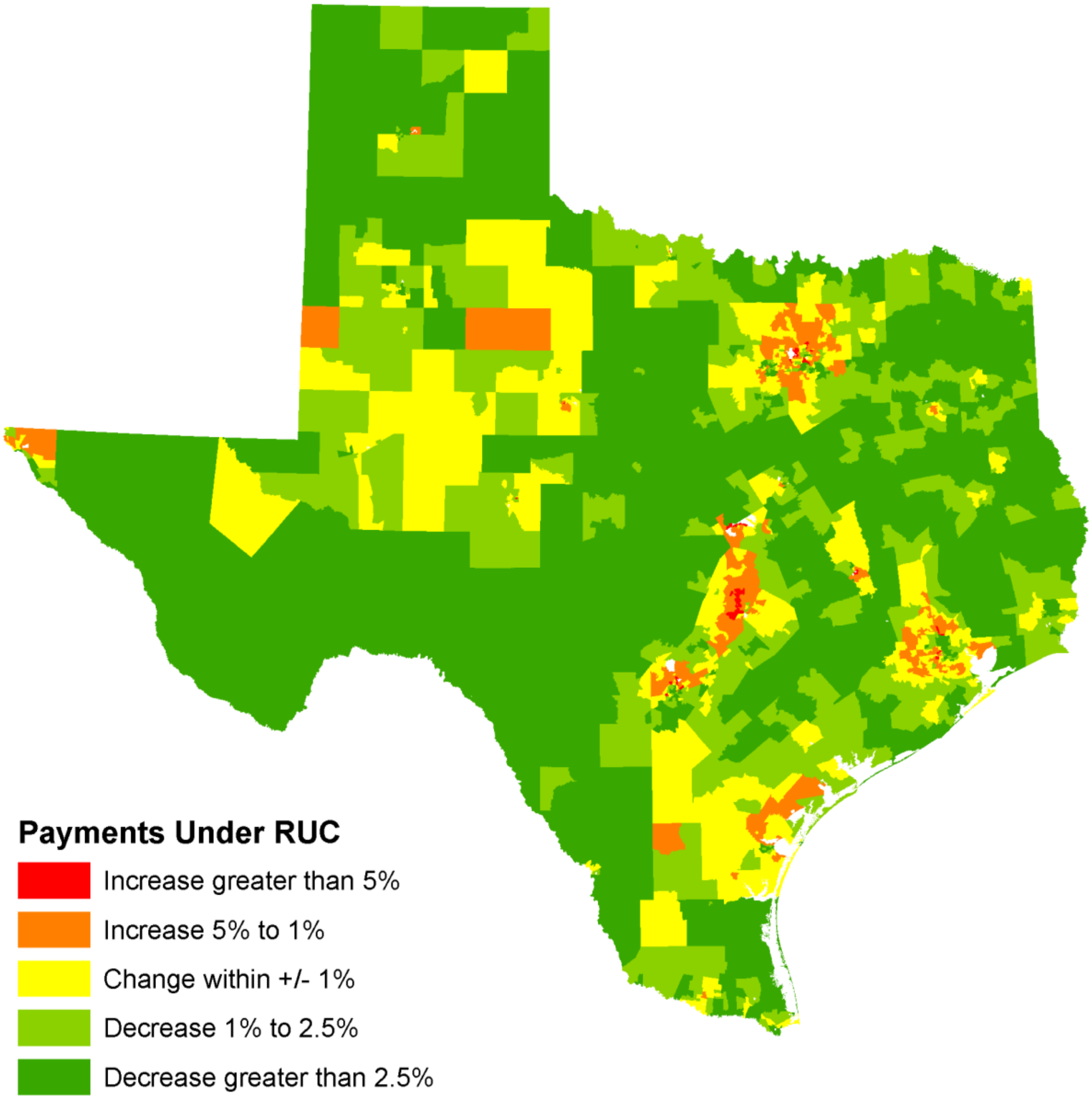
OREGON

Oregon presents one of the clearest pictures of the estimated savings for rural residents of a RUC. A few of Oregon's urban regions are expected to pay slightly more under the RUC, with almost the entirety of Oregon east of the Cascades paying less. Most of Oregon's smaller towns and cities are also expected to pay less due to differences in fuel type and efficiency compared to the greater Portland area.



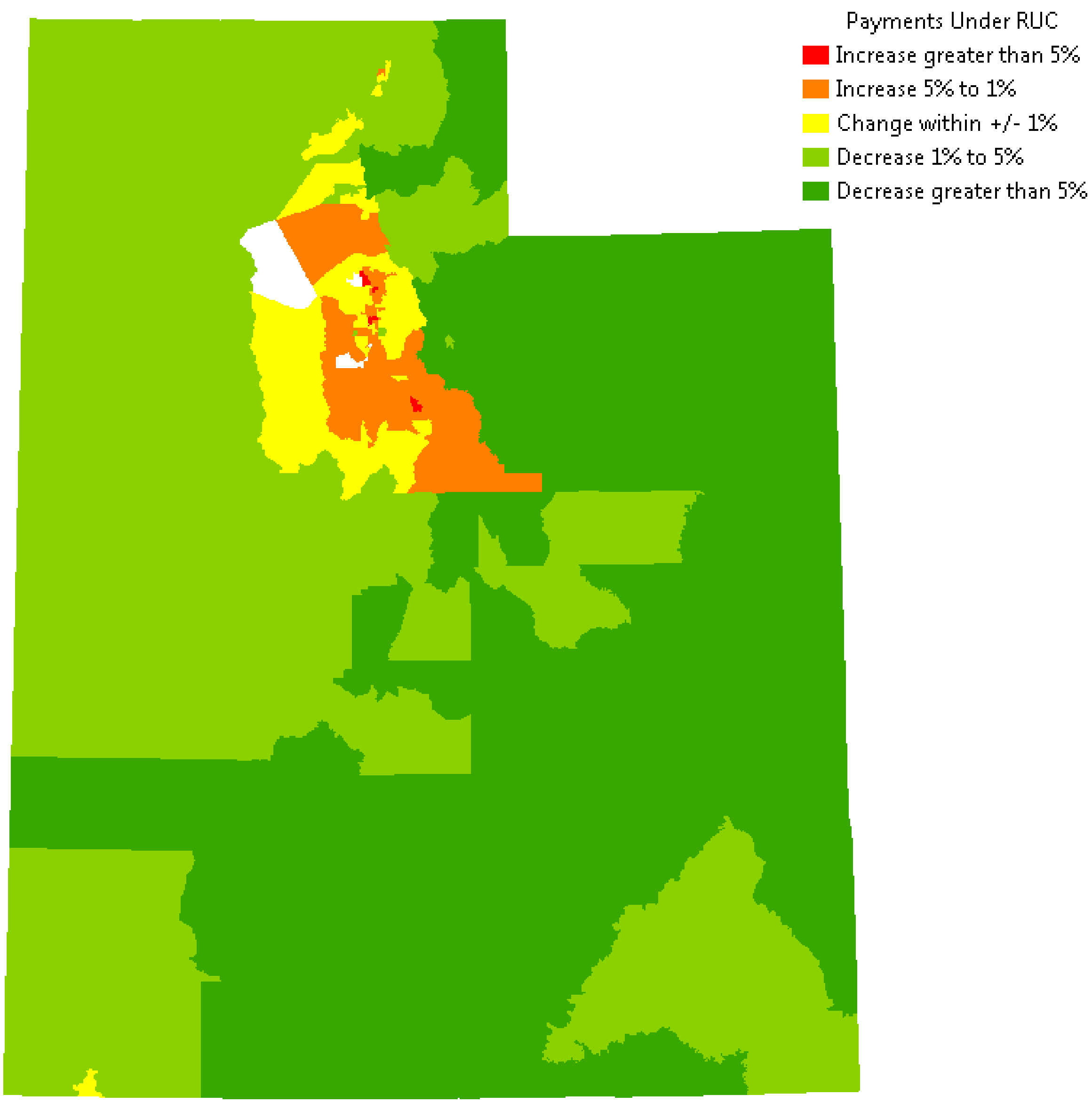
TEXAS

The very high prevalence of flex fuel vehicle registrations in Texas leads to a more complex story in the map below. The analytic framework assumes that 50 percent of flex/biofuel miles are untaxed under the gas tax. In western Texas where the prevalence of this fuel type sometimes exceeds 25 percent, some tracts see slight increases. The main areas of increases continue to be in urban areas, mirroring other states. This is especially true in the metro Austin area, whereas tracts in downtown Houston are expected to save somewhat. There are fewer tracts predicted to have large savings than in other states, with the financial impacts in generally appearing more balanced when speaking about urban, mixed and rural portions of households statewide.



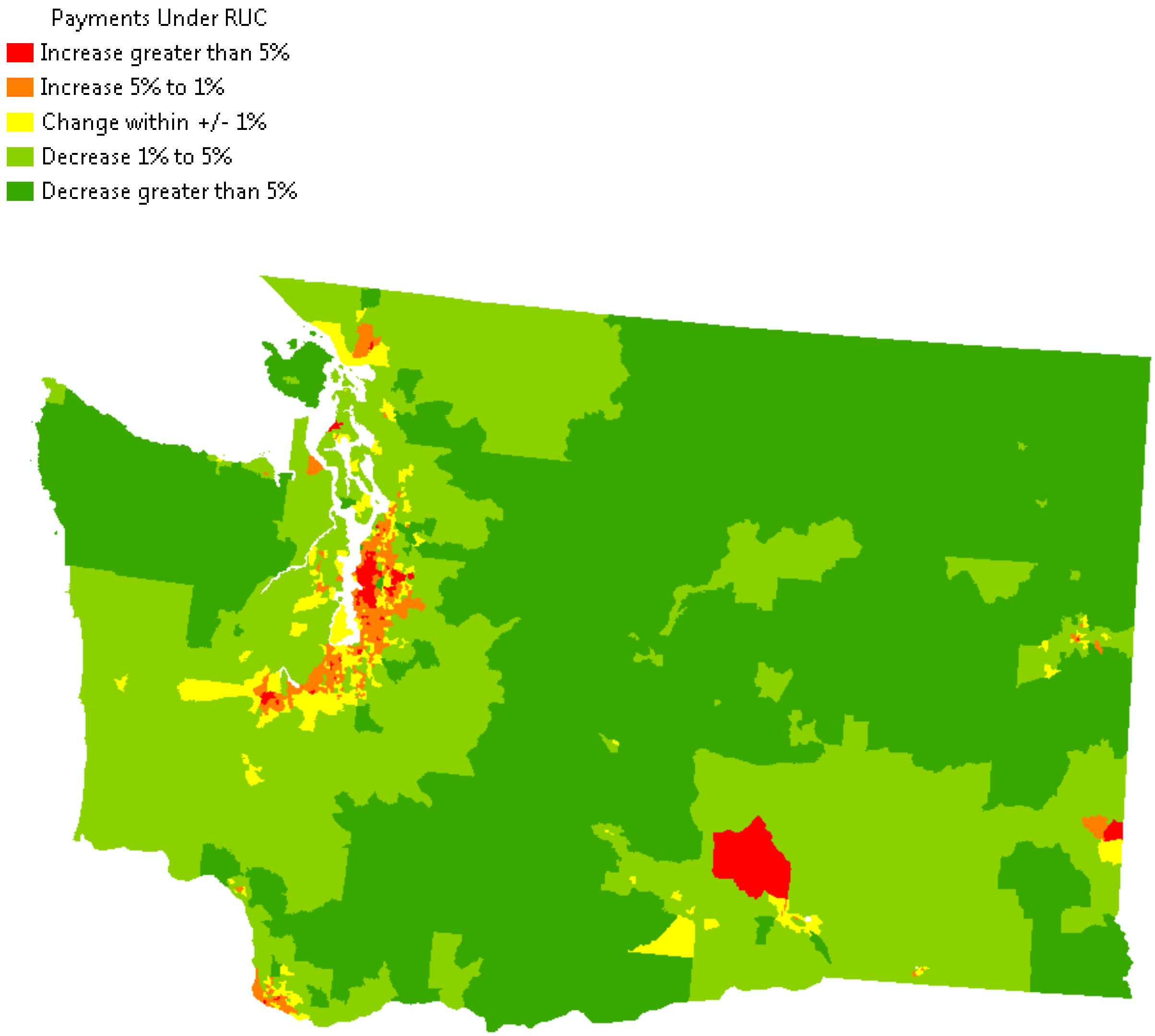
UTAH

Only a few urban tracts in the Salt Lake and Provo areas see increases of greater than 5 percent under a RUC. Most of the households in these more populated areas of Utah pay less than 5 percent more while significant portions of the state see reductions in excess of 5 percent. In the St. George area, higher non-gasoline vehicle penetration keeps the change in payments within 1 percent of the gasoline tax estimate.



WASHINGTON

In Washington, the increases in payments are clearly focused in the greater Seattle area and all around the Puget Sound region, with lesser increases in Clark County, around Spokane, and near Pullman. The large red tract towards the center of the state has only 8 households and 3 identified vehicles and not likely a significant observation. Much of rural Washington households are estimated to pay less when transitioning to a RUC.



APPENDIX D: VEHICLES

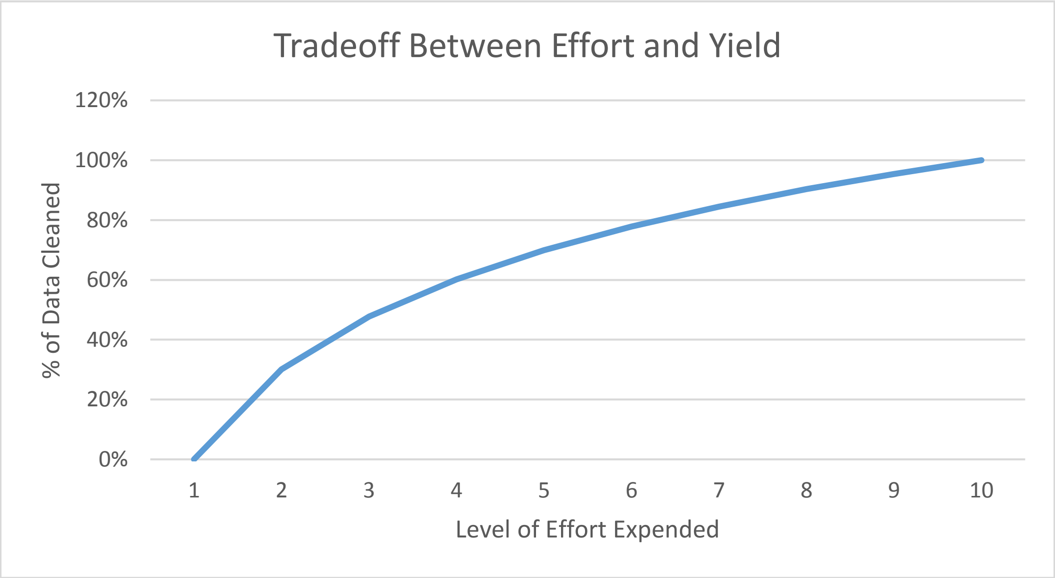
This appendix section focuses on specific pieces of the analysis completed for the eight states covered by the original study. These pieces of analysis provide some lessons learned from the research, but are not necessarily relevant to the future use of the tool.

THE IMPORTANCE OF PRIORITIZING

There is not a linear relationship between time spent decoding and the number of records decoded. The relationship may be similar to that illustrated in Figure 3, or more extreme. Working with this much data requires the analyst to focus on data manipulation that yields the greatest economy of matches. At some point, incomplete records had to be accepted in order to not delay other processes in the workflow. Unfortunately, if the decoding and matching process is halted too early, it could produce inaccurate results later in the analysis. Working with this much data demands a systematic plan involving the prioritization and treatment of elements in as efficient a manner as possible.

There were enormous quantities of data, which arrived at different times. As new data arrived, it was necessary to reevaluate which records were prioritized for processing. As discussed in the subsection on Standardizing and Leveraging Multiple Databases, there are strengths inherent in working with such a large dataset as well as challenges. The section specifically discusses how data received was of varying quality, but in general one of the states provided enough information on a vehicle to improve some of the other states' data.

Figure 3. Unequal Returns to Time and Effort



It is valuable to recognize early on that not all data is necessarily relevant to the analysis. Each of the analytic stages gives us a chance to track, isolate, code and potentially reduce the volume of data with which we are working. At all times, records were prioritized based on volume of occurrence in available data to make the most efficient usage of time, while allowing for a good-better-best scenario of data discovery based on available project time/duration.

IDENTIFYING VEHICLE TYPES FOR EXCLUSION

One of the first opportunities to pare down the volume of active records, was from examination of the layout of the state databases. Some databases contained a vehicle type field that showed that many of the vehicle registrations provided were not within the scope of the study. We made a quick check for any obvious misclassifications, and then created a binary to begin isolating records that are outside of the scope. These records we no longer needed to concern ourselves with and we generally did not decode and geo-locate them. The most important categories for exclusion were commercial and heavy duty trucks. The following diagram shows the vehicle types provided by various states.

Figure 4. Vehicle Type Classes in Source Data

Composition of Stated Vehicle Types by State Database						
Arizona	Idaho	Montana	Oregon	Utah	Washington	California
Not Supplied	CAR	PC	Car - Chassis	Not Supplied	Not Supplied	Auto
	TRK	PC Low Speed	Car - Convertible			Commercial
	BUS	TK Heavy Truck Farm MGCW	Car - Coupe			
	CYL	TK Heavy Truck Farm MGVW	Car - Hatchback			
	MHM	TK Heavy Truck MGCW	Car - Sedan			
	NTK	TK Heavy Truck MGVW	Car - SUV			
	CTK	TK Light Truck	Car - Wagon			
	NEV		Motor Home - Motor Home			
	NBS		SUV - Chassis			
	CBS		SUV - Convertible			
			SUV - Pickup			
			SUV - SUV			
			SUV - Wagon			
			Truck - Chassis			
			Truck - Comm Pickup/Van			
			Truck - Pickup			
			Van - Chassis			
			Van - Comm Pickup/Van			
			Van - Full-Size			
			Van - Mini-Van			
			Van - Wagon			

Exclude
Good
To Investigate

While going through the records and doing basic checks on variable coding and putting binary restrictors on data that was outside of our scope, we started to notice several things:

1. Non-standardized classifications or fields (i.e. spelling mistakes, identical records with different abbreviations)
2. Abnormal records – vehicle classes, either identified or not, that we had had not expected to encounter, which were not limited to:
    a. Trailers and other incomplete vehicles
    b. Scooters and Mopeds
    c. Low Speed Vehicles (i.e. golf carts)

These types of issues are absolutely to be expected when working with any large database, or raw versions of registries, and were identified so they could be addressed in future steps of the analysis. These types of occurrences make cleaning a dataset for analysis more complicated. In the future, we would likely make as specific as possible requests of state agencies, or opt to only receive VIN information and work with standardized outputs from vPIC.

STANDARDIZING AND LEVERAGING MULTIPLE DATABASES

When possible we standardize fields across states. Most states did not have clearly documented variable libraries and in order to work with all databases concurrently values needed to be reconciled to a single set of values. This is especially true for states that provided some fuel type information. In the cases we encountered, each database had its own nomenclature, and typically more detail on the specific type of fuel a vehicle was using than we were able to realistically use. It was not realistic to work with more than the 6 categories in the final analysis and tool.

By standardizing across databases, we were also able to apply information from one database to the other. This allowed us to correct typographical errors in one database by relying on decoded information from another database, for example. One especially usefully connection was in linking successfully decoded information from VINs to a database that used a large amount of abbreviations in makes and models. These abbreviations could be determined during the manual review process and linked with the corrected vehicle information.

EDR GROUP

APPENDIX E: CODE

Text below the line is copied directly from the VBA module in the Excel workbook.

```
Sub ProtectTool()
' This routine is run from the Visual Basic Editor window
' Use it to protect the tool after making changes

    Sheet2.Protect "RUC_UMR"
    Sheet5.Protect "RUC_UMR"

    Sheet8.Protect "RUC_UMR1"
    Sheet7.Protect "RUC_UMR2"
    Sheet6.Protect "RUC_UMR3"

End Sub

Sub UnprotectTool()
' This routine is run from the Visual Basic Editor window
' Use it to unprotect the tool's sheets in order to make changes
' These passwords represent the sheet protection passwords with which
the sheet was delivered

    Sheet2.Unprotect "RUC_UMR"
    Sheet5.Unprotect "RUC_UMR"

    Sheet8.Unprotect "RUC_UMR1"
    Sheet7.Unprotect "RUC_UMR2"
    Sheet6.Unprotect "RUC_UMR3"

End Sub

Sub RunAnalysis()
' This is the core program method for the tool.
' It runs upon pushing the "Run Analysis" button control on the
"Results" sheet.
' It includes calls to other subroutines.

    Dim cSht As Worksheet
    Dim n As Long 'last row

    Set cSht = Worksheets("Calculations")

' Unprotect sheets to allow writing
    cSht.Unprotect "RUC_UMR"
    Worksheets("Results").Unprotect "RUC_UMR"
    Worksheets("Results").Activate
```

```
' Clear any previous runs/data
    n = cSht.Cells.Find("*", SearchOrder:=xlByRows,
SearchDirection:=xlPrevious).Row
    cSht.Range("A3:J" & n).Clear

' Set up calculations only for tracts with vehicle, demographic, and
USR/UMR data
    Call putTracts

' Copy down formulas
    n = cSht.Cells.Find("*", SearchOrder:=xlByRows,
SearchDirection:=xlPrevious).Row

    cSht.Range("B2:B" & n) = cSht.Range("B2").Formula
    cSht.Range("B2:B" & n).NumberFormat = "#,##0"

    cSht.Range("C2").Copy cSht.Range("C3:C" & n)
    cSht.Range("D2").Copy cSht.Range("D3:D" & n)
    cSht.Range("E2").Copy cSht.Range("E3:E" & n)
    cSht.Range("F2").Copy cSht.Range("F3:F" & n)
    cSht.Range("G2").Copy cSht.Range("G3:G" & n)

' Based on calculations so far, determine the equivalent rate
    Call GetEquivRate

' Make final calculations using the equivalent rate
    cSht.Range("H2").Copy cSht.Range("H3:H" & n)
    cSht.Range("I2").Copy cSht.Range("I3:I" & n)
    cSht.Range("J2").Copy cSht.Range("J3:J" & n)

' Report statewide results
    Call sumUMR

' Reportect sheets for reviewing safely
    cSht.Protect "RUC_UMR"
    Worksheets("Results").Protect "RUC_UMR"

End Sub

Sub putTracts()
' This method is called by RunAnalysis().
' It sets up the tracts in the calculations sheet for which there is
sufficient data to include in analysis.
' Checking tracts in the most time consuming part of the analysis.
' It may run up to a few minutes for a large state like California.


    Dim sht1 As Worksheet, sht2 As Worksheet
    Dim rngDem As Range, rngVeh As Range, rng2010 As Range, rngRet As
Range
```

```
    Dim arrDem As Variant, arrVeh As Variant, arr2010 As Variant,
interm As Variant, final As Variant
    Dim LastRowDem As Long, LastRowVeh As Long

    ReDim arrDem(0) 'will contain tractIDs for complete demographic
records
    ReDim arrVeh(0) 'will contain tractIDs for complete demographic
records
    ReDim interm(0) 'will contain tractIDs that are in RUCA2010 and
conDem
    ReDim final(0)  'will contain tracts with vehicle information and
in interm(ediate)

    Set sht1 = Worksheets("Demographics")
    Set sht2 = Worksheets("Vehicles")
    Set rng2010 = Worksheets("Tracts").Range("A2:A72532")

    arr2010 = rng2010.Value2

'Find Last Row
    LastRowDem = sht1.Cells.Find("*", SearchOrder:=xlByRows,
SearchDirection:=xlPrevious).Row
    LastRowVeh = sht2.Cells.Find("*", SearchOrder:=xlByRows,
SearchDirection:=xlPrevious).Row

    If LastRowDem <> (LastRowVeh) Then
        MsgBox "Vehicle and demographic ranges have different numbers
of entries. Calculations will only be made for tracts in both ranges."
    End If

' Make sure all tracts are in text format
    sht1.Range("A3:A" & LastRowDem).NumberFormat = "@"
    For Each Cell In sht1.Range("A3:A" & LastRowDem)
        Cell.Value = CStr(Cell.Value)
        If Len(Cell.Value) = 10 Then
            Cell.Value = "0" & Cell.Value
        End If
    Next

    sht2.Range("A3:A" & LastRowVeh).NumberFormat = "@"
    For Each cl In sht2.Range("A3:A" & LastRowVeh)
        cl.Value = CStr(cl.Value)
        If Len(cl.Value) = 10 Then
            cl.Value = "0" & cl.Value
        End If
    Next

' Set ranges and name them
    Set rngDem = sht1.Range("A3:K" & LastRowDem)
    ActiveWorkbook.Names.Add Name:="Demog", RefersTo:=rngDem
    Set rngVeh = sht2.Range("A3:O" & LastRowVeh)
```

```
    ActiveWorkbook.Names.Add Name:="Vehic", RefersTo:=rngVeh

' Extract tracts from ranges into arrays
    For r = 1 To (LastRowDem - 2)
        If IsNumeric(rngDem.Cells(r, 2)) And _
           IsNumeric(rngDem.Cells(r, 3)) And _
           IsNumeric(rngDem.Cells(r, 4)) And _
           IsNumeric(rngDem.Cells(r, 5)) And _
           IsNumeric(rngDem.Cells(r, 6)) And _
           IsNumeric(rngDem.Cells(r, 7)) And _
           IsNumeric(rngDem.Cells(r, 8)) And _
           IsNumeric(rngDem.Cells(r, 9)) And _
           IsNumeric(rngDem.Cells(r, 10)) And _
           IsNumeric(rngDem.Cells(r, 11)) Then
            arrDem(UBound(arrDem)) = CStr(rngDem.Cells(r, 1).Value2)
            ReDim Preserve arrDem(UBound(arrDem) + 1)
        End If
    Next
    ReDim Preserve arrDem(UBound(arrDem) - 1)

    For r = 1 To (LastRowVeh - 2)
        If IsNumeric(rngVeh.Cells(r, 2)) And _
           IsNumeric(rngVeh.Cells(r, 3)) And _
           IsNumeric(rngDem.Cells(r, 4)) And _
           IsNumeric(rngDem.Cells(r, 5)) And _
           IsNumeric(rngDem.Cells(r, 6)) And _
           IsNumeric(rngDem.Cells(r, 7)) And _
           IsNumeric(rngDem.Cells(r, 8)) And _
           IsNumeric(rngDem.Cells(r, 9)) And _
           IsNumeric(rngDem.Cells(r, 10)) And _
           IsNumeric(rngDem.Cells(r, 11)) And _
           IsNumeric(rngDem.Cells(r, 12)) And _
           IsNumeric(rngDem.Cells(r, 13)) Then 'possibly also check if
is faction?
            arrVeh(UBound(arrVeh)) = CStr(rngVeh.Cells(r, 1).Value2)
            ReDim Preserve arrVeh(UBound(arrVeh) + 1)
        End If
    Next
    ReDim Preserve arrVeh(UBound(arrVeh) - 1)

' Determine final range by comparing three arrays
    If Err.Number <> 0 Then
            Err.Number = 0
    End If
    On Error Resume Next
    For cnt = 0 To UBound(arrDem)

        x = Application.WorksheetFunction.Match(arrDem(cnt), arr2010,
False)

        If Err.Number = 0 Then
```

```
            interm(UBound(interm)) = arr2010(x, 1)
            ReDim Preserve interm(UBound(interm) + 1)
        End If

        If Err.Number <> 0 Then
            Err.Number = 0
        End If

    Next
    ReDim Preserve interm(UBound(interm) - 1)
    x = 0

    On Error Resume Next
    For cnt = 0 To UBound(arrVeh)

        x = Application.WorksheetFunction.Match(arrVeh(cnt), interm,
False) - 1

        If Err.Number = 0 Then
            final(UBound(final)) = interm(x)
            ReDim Preserve final(UBound(final) + 1)
        End If

        If Err.Number <> 0 Then
            Err.Number = 0
        End If

    Next
    ReDim Preserve final(UBound(final) - 1)

' Paste results into calculations sheet
    Set rngRet = Worksheets("Calculations").Range("A2:A" & (2 +
UBound(final)))
    rngRet.NumberFormat = "@"
    rngRet = Application.Transpose(final)

End Sub

Sub GetEquivRate()
' This method calculates the equivalent rate based on estimated fuel
tax payments and total VMT.
' It stores the value in the "Results" sheet for later review.

    Dim FTaxes As Range
    Dim RUC_VMT As Range
    Dim cSht As Worksheet

    Set cSht = Worksheets("Calculations")

    Dim n As Long
    Dim totalFT As Double
```

```
    Dim totRUC_VMT As Double

' Find end of range
    n = cSht.Cells.Find("*", SearchOrder:=xlByRows,
SearchDirection:=xlPrevious).Row

    Set FTaxes = cSht.Range("f2:f" & n)
    Set RUC_VMT = cSht.Range("g2:g" & n)

'Sum over two ranges
    totalFT = WorksheetFunction.Sum(FTaxes)
    totalRuc_VMT = WorksheetFunction.Sum(RUC_VMT)

'Calculates and stores equivalent rate
    Worksheets("Results").Range("B3").Value = totalFT / totalRuc_VMT

End Sub

Sub sumUMR()
' This method is the final analytic step that inserts results into the
"Results" sheet.
' Totals are calculated by inspecting records and adding them into the
right bin.


    Dim cSht As Worksheet
    Dim rSht As Worksheet
    Dim UMRTable As Range
    Dim Tracts As Range

    Dim lastRow As Long
    Dim UMR As String    ' Urban-Mixed-Rural classification
    Dim FTP As Double    ' Fuel Tax Paid - single tract
    Dim RCP As Double    ' RUC Paid - single tract
    Dim UFP As Double    ' Fuel Tax Paid - all urban tracts
    Dim MFP As Double    ' Fuel Tax Paid - all mixed tracts
    Dim RFP As Double    ' Fuel Tax Paid - all rural tracts
    Dim URP As Double    ' RUC Paid - all urban tracts
    Dim MRP As Double    ' RUC Paid - all mixed tracts
    Dim RRP As Double    ' RUC Paid - all rural tracts

    Set cSht = Worksheets("Calculations")
    Set rSht = Worksheets("Results")
    Set UMRTable = Worksheets("Tracts").Range("A2:D72532")

' ID relevant range
    lastRow = cSht.Cells.Find("*", SearchOrder:=xlByRows,
SearchDirection:=xlPrevious).Row
    Set Tracts = cSht.Range("A2:A" & lastRow)

' Inspect tracts and total
```

```
    For Each tract In Tracts
        UMR = Application.VLookup(tract, UMRTable, 4, False)
        FTP = cSht.Range("A2:I" & lastRow).Cells(tract.Row - 1,
6).Value2
        RCP = cSht.Range("A2:I" & lastRow).Cells(tract.Row - 1,
8).Value2
        If UMR = "Urban" Then
            UFP = UFP + FTP
            URP = URP + RCP
        End If
        If UMR = "Mixed" Then
            MFP = MFP + FTP
            MRP = MRP + RCP
        End If
        If UMR = "Rural" Then
            RFP = RFP + FTP
            RRP = RRP + RCP
        End If
    Next

' Insert results into "Results" sheets
    rSht.Range("C7").Value2 = UFP
    rSht.Range("C8").Value2 = MFP
    rSht.Range("C9").Value2 = RFP
    rSht.Range("D7").Value2 = URP
    rSht.Range("D8").Value2 = MRP
    rSht.Range("D9").Value2 = RRP

End Sub

Function HHDVMT(tract As String) As Double
' This function is used in the first calculation in the "Calculations"
sheet.
' It is copied down by the RunAnalysis() method to apply to all
tracts.
' It implements the Transferability Statistics equations by pulling
variables and coefficients.


    Dim Eqs As Worksheet
    Dim Dem As Worksheet
    Dim USRTable As Range
    Dim States As Range
    Dim RegUSRKeys As Range

    Set Eqs = Worksheets("Equations")
    Set Dem = Worksheets("Demographics")
    Set USRTable = Worksheets("Tracts").Range("A2:B72532")
    Set States = Worksheets("States").Range("A2:V52")
    Set RegUSRKeys = Eqs.Range("A3:A20")
```

```
    Dim EqRow As Integer
    Dim TractRow As Long
    Dim HHs As Double
    Dim Inc As Double
    Dim Cell As Range
    Dim RegUSRKey As String

' Find correct equation row to use for Census tract
    RegUSRKey = Application.VLookup(Left(tract, 2), States, 5, False)
& Application.VLookup(tract, USRTable, 2, False)
    EqRow = RegUSRKeys.Find(RegUSRKey, _
                            LookIn:=xlValues, _
                            SearchOrder:=xlByRows, _
                            SearchDirection:=xlNext, _
                            MatchCase:=False).Row

' Find correct tract row in "Demographics" to match "Calculations"
    TractRow = Dem.Range("A:A").Find(tract, _
                                    LookIn:=xlValues, _
                                    SearchOrder:=xlByRows, _
                                    SearchDirection:=xlNext, _
                                    MatchCase:=False).Row

' Store locally demographic data used multiple times in teh
calculations
    HHs = Dem.Range("B" & TractRow).Value
    Inc = Dem.Range("C" & TractRow).Value

' Avoid possible errors when calculating logs
    If Not Inc > 0 Then
        Inc = 1
    End If

' Apply the equation to the demographic characteristics row
    If Not HHs > 0 Then
        HHDVMT = 0
    Else
        HHDVMT = Eqs.Range("D" & EqRow).Value + _
                 Eqs.Range("E" & EqRow).Value * Inc + _
                 Eqs.Range("F" & EqRow).Value *
Application.WorksheetFunction.Ln(Inc) + _
                 Eqs.Range("G" & EqRow).Value * Dem.Range("D" &
TractRow).Value / HHs + _
                 Eqs.Range("H" & EqRow).Value * Dem.Range("E" &
TractRow).Value / HHs + _
                 Eqs.Range("I" & EqRow).Value * Dem.Range("F" &
TractRow).Value / HHs + _
                 Eqs.Range("J" & EqRow).Value * Dem.Range("G" &
TractRow).Value / HHs + _
                 Eqs.Range("K" & EqRow).Value * Dem.Range("H" &
TractRow).Value / HHs + _
```

```
                 Eqs.Range("L" & EqRow).Value * Dem.Range("I" &
TractRow).Value / HHs + _
                 Eqs.Range("M" & EqRow).Value * Dem.Range("J" &
TractRow).Value / HHs + _
                 Eqs.Range("N" & EqRow).Value * Dem.Range("K" &
TractRow).Value / HHs
     End If

End Function
```