EBP

Supporting Rural Communities Through Clean Transportation Investments

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1. Executive Summary

Across the Northeast, policymakers are striving to come up with fair and equitable ways to improve our transportation system, reduce greenhouse gas emissions, and transition to a cleaner future. There are many ways we can work to achieve these goals, and nearly all require significant investment in our aging transportation infrastructure.

One approach currently being considered is the Transportation and Climate Initiative (TCI), which is intended to reduce greenhouse gas emissions from on-road vehicles across the region from Maine to Virginia. The current TCI proposal is a "Cap and Invest" program that would put a limit on allowable carbon emissions from cars and trucks and require fuel distributors to pay for their share of those emissions. This would create a pool of funds for states to use to further reduce emissions through whatever clean transportation investments work best for them and can also support states' efforts to address key deficiencies in our transportation systems.

This report examines a variety of ways transportation funding—whatever the source—might be used to reduce emissions while addressing deficiencies in rural transportation systems and provides a framework for assessing these policies. Some of the "solutions" examined may also be applicable in more urbanized areas.

We need better ways to get from place to place; this has been repeatedly demonstrated in polling and the public discourse throughout the region. Overall, voters say that the transportation system in their state –including "highways, roads, and public transportation like trains or buses" – deserves poor marks. Over 75 percent of people across the region offer up a "C" or lower grade, while nearly one-in-three provides the poorest marks of "D" (20%) or "F" (12%).

Why Focus on Rural Communities?

After consulting in early 2018 with partner organizations and state agencies involved in the TCI process, The Nature Conservancy identified a need to address a gap in knowledge and research on the transportation needs of rural communities and the solutions that might work best. People in rural areas are often overlooked in discussions about clean transportation investments, at least in part because there are fewer people and fewer emissions coming from these areas. But engaging these communities and building support for programs that aim to modernize our transportation system is essential for a variety of reasons:

- Rural residents drive more and often have no choice but to do so for necessities such as work, school, medical visits, and shopping. Although rural communities only accounted for 18% of the 546 billion vehicle miles traveled (VMT) in the TCI states in 2018, rural TCI counties average 43% more VMT per capita than their urban counterparts. As such, measures that increase the cost of driving will hit rural residents harder than many others.
- There are a lot of lower income people living in rural counties in the TCI states who spend a large percentage of their income on transportation.
- People in rural areas tend to drive on higher speed roads and drive cars that are older, with fewer safety features. The number of fatalities per 100 million VMTs is 58% higher in rural TCI counties.
- Rural counties have higher percentages of two key transportation access-challenged populations: the elderly and people with disabilities.
- Rural counties may only be 13% of the overall population of TCI states, but they make up 211 of the 378 counties in the region. Their support is, therefore, vital to achieving the broad-based consensus necessary to drive change.

Of course, rural communities are not the only important constituency that must be considered for policy improvements in the TCI process—or in any dialogue about a cleaner and more just transportation future. The transportation needs in urban communities are significant and complex, and the gains that can be made in terms of clean air, quality of life, equity, and economic growth cannot be understated. Underserved and overburdened residents in urban and suburban areas need the significant emissions reductions and access to clean, reliable transportation options that can be realized if we make good policy choices. The conversation about modernizing our transportation system needs to be broad and should be inclusive of all communities in a just and equitable manner.

What is the purpose of this report?

The goal of this report is to offer a methodology for examining potential clean transportation investments that could be made in rural communities using funds that come from a program like TCI, economic stimulus, or from some other mechanism. The goal is not to be prescriptive, but rather to provide an organized way of thinking that lets policymakers see clearly what rural communities have to gain from transportation improvements.

The research was compiled by EBP at the request of The Nature Conservancy.

What are the report's key findings?

The report looks at a variety of potential transportation improvements that could be available in rural and small-town communities and examines their potential impact over a range of benefits. These benefits include not only reductions in emissions that cause climate change, but also important factors such as stimulating economic growth, public health and safety improvements, access to reliable transportation, improving equity, and increasing resilience.

Potential "solutions" examined included:

- Encouraging adoption of new and cleaner vehicle technologies for personal transportation;
- Converting public vehicle fleets to electric or hybrid electric technologies;
- Enabling conversion of freight vehicles that pass through the region to electric technologies;
- Electrification of rural truck stops;
- Facilitating increased use of rail and marine routes for freight transport;
- Improving intra-regional and local rural public transportation and shared mobility options in rural areas;
- Improving inter-regional transportation in rural areas;
- Improving access to broadband internet in rural areas; and
- Improving town centers in small towns.

The systematic review of these improvements yielded insights demonstrating that the potential policies being considered have a lot to offer:

- Replacing only 10% of rural personal vehicles with Battery-Electric Vehicles (BEVs) would eliminate roughly 1.4 million tons of GHG emissions every year. Even replacing the same number of vehicles with hybrids would eliminate over 700,000 tons of GHG emissions annually.
- Converting public vehicle fleets to electric vehicles could offer lots of benefits. Every transit bus replaced with an electric counterpart saves 52 tons of emissions per year, and school buses can save between 29 and 52 tons per year. Electrification of public vehicle fleets can also result in significant savings on maintenance and fuel costs.

- Although many think of public transit as an option primarily for urbanized areas, the analysis examines how investment in smaller local systems, expanding urban systems outwards, and improving intraregional systems can offer benefits. Every investment of $1 million in rural transit results in 55,000 fewer single occupancy vehicle trips, reducing 142 tons of GHG emissions. It also significantly increases access to health facilities, shopping, and jobs for rural residents, particularly for the differently abled and the elderly.
- Increasing availability of broadband internet services has become an important consideration in discussion of transportation as it not only increases access to telecommuting, it also has been proven to facilitate job growth in more rural regions, thereby reducing VMTs in rural communities. It also brings economic growth to communities. One World Bank study shows that a 10% increase in broadband penetration in developed countries leads to an average increase of 1.38% to GDP. With the advent of the COVID-19 pandemic, broadband access is increasingly important for equity issues around remote schooling.

It is our hope that as legislators, state agencies, and Governors are considering the impacts of climate change, the need for improvements to our transportation systems, and proposals like TCI that are attempting a region-wide approach to these issues, that they will (a) include rural and small town communities in their thinking as they craft solutions and (b) that they will make policy choices that look to maximize the available opportunities. This will help ensure that they obtain the best economic value, via cost-savings or job creation, while improving transportation access, and reducing transportation emissions.

2. Review of Existing Work

There is a significant body of relevant literature related to TCI, but it generally does not address rural-urban differences in needs or impact. A prominent and comprehensive study of the environmental and economic effects of a cap and invest program like TCI was published by the Georgetown Climate Center in 2015.[1] The Georgetown Climate Center report presents a comprehensive analysis of current mobile-source GHG emissions in the TCI region and estimates how investment options would help TCI states reduce emissions and improve public health. The report also estimates how certain policies enabled by the TCI agreement could generate needed state and local revenues for transportation projects, and how these policies would likely generate economic benefits for the region.

Following the release of the draft TCI Memorandum of Understanding (MOU) in December 2019, additional modeling was completed. The modeling developed a business-as-usual case for reference and compared it to three cap-and-invest scenarios.[2] It evaluated each scenario in terms of energy and emissions, public health, and economic impacts. They estimated that the TCI scenarios would reduce emissions by 20 to 24 percent by 2032 and would result in between $3 and $10 billion in public health benefits from reduced air pollution, increased physical activity, and reduced vehicular crashes. Economic modeling predicted business cost savings from reduced fuel expenditures, lower congestion, and reduced vehicle operating and maintenance costs. Their analysis estimated an annual increase in GDP in the region of $0.7 to $2.8 billion and the generation of between 2,400 and 10,300 jobs per year, depending on the level of TCI investment.[3]

Following the release of the draft MOU, six regional listening sessions were hosted, with 500 stakeholders participating. An additional 1,000 people participated in regional workshops. In addition, TCI received 1,200 submissions via a public input portal. Businesses, environmental groups, and non-profit groups from throughout the TCI region provided input on the draft MOU.[4]

Additional studies evaluated policies and programs designed to curb emissions both within and outside of the TCI region. One report evaluated how different policies, including transportation-focused initiatives, can support a path to clean energy in Northern New England. It estimated impacts of policies that enable plug-in electric vehicle adoption, including electric school bus and transit vehicle adoption in terms of GHG, jobs, and equity.[5] Outside of the TCI region, one study considered the equity implications of California's cap and trade program by highlighting impacts on residents living in poverty and people of color.[6] Other studies focused on the implementation process of specific types of investments, such as electrification of public fleets[7] and personal electric vehicle adoption.[8]

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[1] Pacyniak et al. "Reducing Greenhouse Gas Emissions from Transportation: Opportunities in the Northeast and Mid-Atlantic." Washington DC: Georgetown Climate Center, November 2015.

[2] Evaluating the Potential Environmental and Economic Benefits and Costs of a Cap and Invest Program for Transportation Emissions in the TCI Region. TCI, Dec. 2019.

[3] Webinar: Draft MOU & 2019 Cap-and-Invest Modeling Results, December 2019. https://www.transportationandclimate.org/sites/default/files/TCI%20Public%20Webinar%20Slides_20191217.pdf

[4] "Organizations and businesses respond to TCI Draft MOU release." December 17, 2019. https://www.transportationandclimate.org/organizations-and-businesses-respond-tci-draft-mou-release-0

[5] VEIC, "Advancing Clean Energy Investment in Northern New England." February 2019.

[6] Cushing, L.J. et al. "A Preliminary Environmental Equity Assessment of California's Cap-and-Trade Program." September 2016.

[7] EV Smart Fleets. "Capturing the Federal EV Tax Credit for Public Fleets: A Case Study of a Multi-Jurisdictional Electric Vehicle Fleet Procurement in Alameda County, California." April 2017.

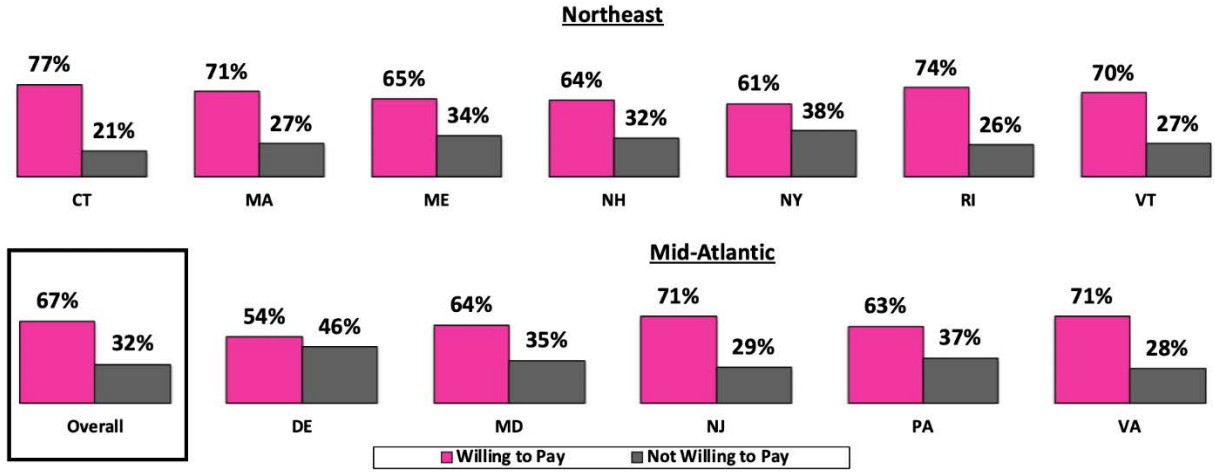
[8] Gatti, Daniel. "Union of Concerned Scientists: Rural Drivers Have Most to Gain from Clean Vehicles." The Daily Yonder, Feb. 15, 2019.

Despite the multitude of studies, most findings are primarily focused on urban areas. In the TCI region, the majority of transportation GHG emissions are generated in urban areas[9], and solutions such as compact development around traditional transit services are often envisioned primarily for urban contexts. Benefits identified in the existing TCI region modeling, such as reduced vehicle travel and less time in traffic, would accrue more meaningfully to urban dwellers.

Some residents and elected officials from rural areas, as well as primarily rural states such as the northern New England states, have described the anticipated increases in fuel prices as regressive, penalizing car-dependent rural areas. They also indicate a belief that TCI will increase transportation costs for rural people but primarily fund improvements in urban areas.Findings from independent polling and public discussion sessions conducted in rural areas in the proposed TCI region, hosted by The Nature Conservancy, echo these sentiments.

Nearly all respondents indicated that they have no alternatives to driving to access jobs and services. At the same time, regardless of political affiliation, the majority of respondents agree that climate change will adversely affect them, and they support transportation improvements. Respondents support a broad range of solutions including replacing existing conventional vehicles with clean vehicles, improving their ability to work and shop from home with increased high-speed internet access, and finding ways to ease the travel burden though more home deliveries.[10]

Figure 1: Share of Respondents Willing to Pay More to Fund Clean Transportation Choices



Source: New Bridge Strategies and FM3 Research (September 2019), "Small Town & Rural Voters' Views of Investments Related to the Transportation and Climate Initiative a Clean Transportation Fund in the Northeast & Mid-Atlantic."

Polling data suggest that rural and small-town voters in the TCI region support more transformative solutions as well. Around 80% of respondents indicated support for incentives for town center development and increased local transit services between those places and outlying areas, and more than 70% supported increased transit service between major regional destinations.

[9] Pacyniak et al. "Reducing Greenhouse Gas Emissions from Transportation: Opportunities in the Northeast and Mid-Atlantic." Washington DC: Georgetown Climate Center, November 2015.

[10] New Bridge Strategies and FM3 Research (September 2019), "Small Town & Rural Voters' Views of Investments Related to the Transportation and Climate Initiative a Clean Transportation Fund in the Northeast & Mid-Atlantic."

Critically, a full two-thirds of respondents indicated that they were willing to pay more than they already do for these solutions (See Figure 1).[11]

Considering the importance of urban-rural equity in the TCI region, this report complements other studies by focusing exclusively on rural needs and on TCI solutions that address these needs.

[11] New Bridge Strategies and FM3 Research (September 2019), "Small Town & Rural Voters' Views of Investments Related to the Transportation and Climate Initiative a Clean Transportation Fund in the Northeast & Mid-Atlantic."

3. Rural Needs

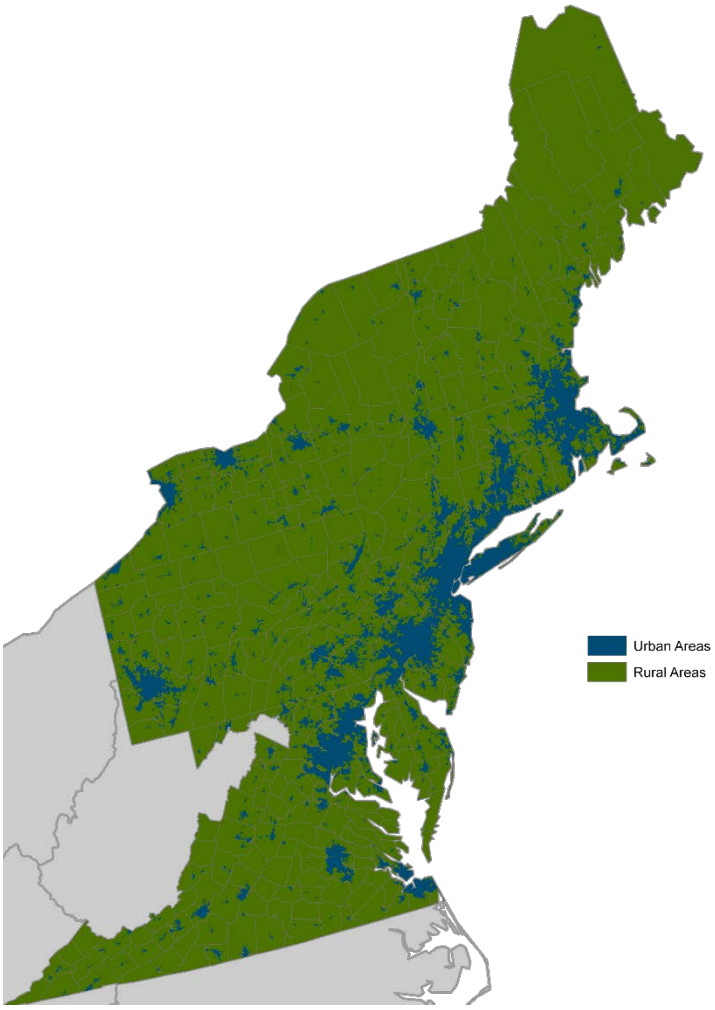
This section provides background and context on transportation priorities in rural areas, with the objective of providing a broad picture of the potential markets for different transportation investment options. In order to establish and understand rural needs, we draw on available data and information on how rural needs and markets are either similar to or meaningfully different from their more urban counterparts. This report section is organized to address the following topics:

- Characteristics of rural communities
- Passenger mobility and access
- Freight mobility and access
- Digital and local connectivity

3.1 Characteristics of rural communities

As shown in Figure 2, the vast majority of the TCI region, by area, is made up of rural land, lying outside of census-defined Urban Areas.

Figure 2 Census-defined Urban Areas in the TCI region



Source: EBP map based on U.S. census Urban Area classification

While the map shows census tract-level classifications, other classification systems define rural and urban at a county level. In our analysis of rural needs, we use Office of Management and Budget definitions of metropolitan and non-metropolitan counties, as well as a more detailed stratification among seven categories of non-metropolitan or rural counties, as defined in Table 1.

Table 1 Classification of Urban and Rural Counties

Classification	Description
Metropolitan (Urban)	All counties defined by the Office of Management and Budget (OMB) as Metropolitan. Metropolitan counties are located within Metropolitan Statistical Areas (MSAs), which generally have a population density greater than 1,000 people per square mile or a total population greater than 250,000 people.
Fringe	Non-metropolitan counties that are (1) adjacent to metropolitan counties or (2) are within MSAs but are relatively rural as determined by (a) having more than 50 percent of the population living outside of an urbanized area or cluster or (b) having a population density lower than 100 people per square mile.
Micropolitan	As defined by the OMB. Micropolitan counties contain one or more urbanized area with a population over 10,000 but less than 50,000 or are adjacent to and linked economically with such a county. (However, per the definition below, counties containing an urbanized area with a population between 10,000-20,000 are classified as Rural Towns.)
Rural Towns	Counties not adjacent to a metropolitan area but with an "urban" population of 2,500-20,000.
Remote	Counties that have either (1) Population density less than ten people per square mile or that (2) are non-metropolitan and do not contain a town of at least 2,500 people.
Agriculture & Extraction	Counties that are strongly dependent economically on either mining or farming activities.
Older age	Counties where 33 percent or more of the population is over 60 years of age. Thirty-three percent captures counties that are in (approximately) the 95th percentile of the number of people over 60.
Destination	Counties that have a large amount of recreational activity or that are retirement destinations.

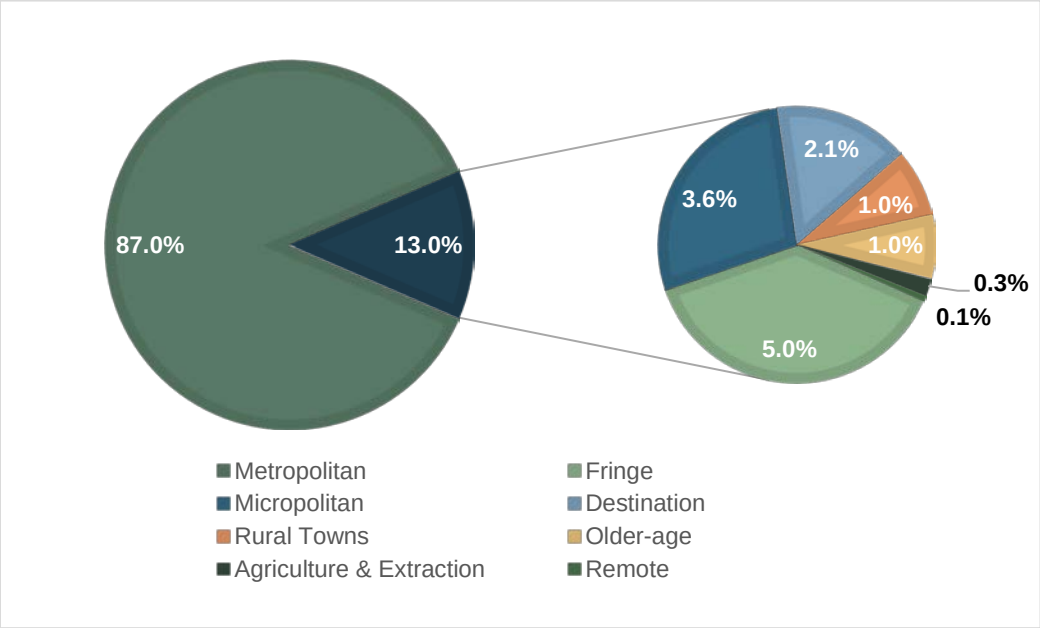
Source: EBP analysis of county characteristics.

In total, there are 71.2 million people living in TCI states as of 2017. Rural (non-metropolitan) counties comprise 211 out of 378 counties but only 13% of the total population or 9.3 million people.[12] Rural areas are characterized by lower density development, as reflected in the discrepancy between the number of rural counties and their share of population. Therefore, solutions developed in urban contexts often require adaptation to rural realities.

However, rural areas are not homogenous. Figure 3 shows the distribution of population in TCI states across all eight county area types. Among rural counties, more than half of TCI rural residents live in fringe or micropolitan counties that share some development characteristics with urban areas, albeit at a smaller scale. When considering TCI strategies, it is just as important to bear in mind the differences across rural communities as it is to consider the unique needs of rural communities compared to metropolitan areas.

[12] 2013-2017 American Community Survey 5-Year Estimates. Note that Rhode Island and Washington, DC are classified as entirely metropolitan in this classification scheme.

Figure 3 TCI Population by County Type



Source: EBP analysis of county characteristics. 2013-2017 American Community Survey.

Rural Demographics

A review of rural demographics reveals that there are some populations within rural communities with distinct needs and vulnerabilities that merit special attention. It also reveals the disparities between rural and urban communities.

Income

Rural areas tend to have lower income levels than urban areas. The average household income in rural parts of TCI states is approximately 28% less than in urban areas.[13] Across TCI states, this gap ranges from 8% lower (MA) to 35% lower (VA). Among rural counties, those that are remote, rural towns, or agriculture and extraction dependent counties are characterized by even lower household incomes (Figure 4). Remote counties and those with agriculture or mining based economies also had higher unemployment rates in 2017 (6.6% and 6.8% respectively) compared to the average for TCI rural (non-metropolitan) counties (6.0%).[14]

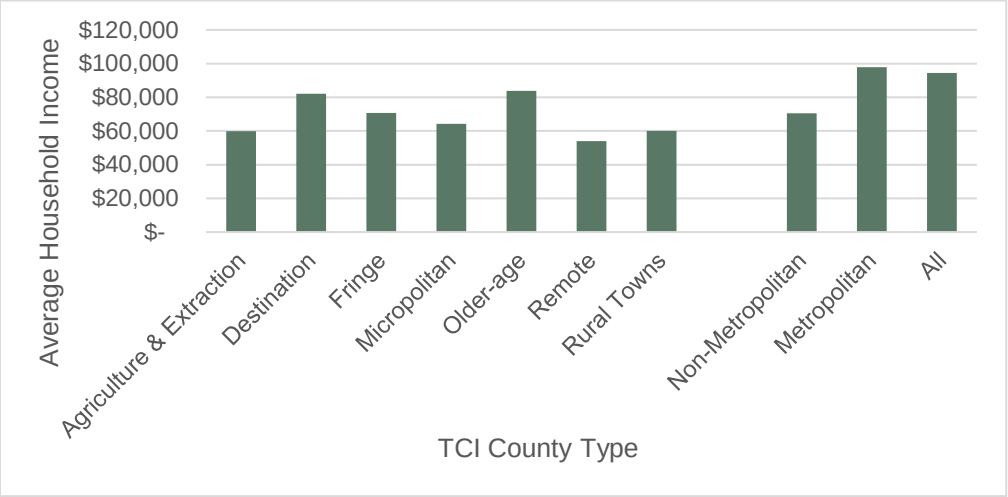
In general, lower incomes in rural areas are often accompanied by lower costs of living. However, as we explore in detail in the section that follows on transportation affordability, household transportation costs in rural areas actually tend to be higher than in urban areas. As a result, rural residents of TCI spend a much greater share of their income (on average 32.8%) on transportation compared to urban residents (who average 21.7%).[15]

[13]EBP analysis of 2013-2017 American Community Survey 5-Year Estimates.

[14] EBP analysis of 2013-2017 American Community Survey 5-Year Estimates.

[15] EBP analysis of HUD Location Affordability Index

Figure 4 TCI Average Household Income by County Type (2017).



Source: EBP analysis of county characteristics. 2013-2017 American Community Survey 5-Year Estimates.

People with Disabilities and Older Adults

Rural areas have relatively older populations, as well as more people with disabilities. In rural counties of the TCI region, the proportion of persons with disabilities is 15.4% compared to 11.3% in metropolitan areas.[16] Additionally, persons over 60 years old comprised 24% of the population in rural parts of the TCI region, compared to 21% in urban areas.[17] Older adults and people with disabilities are less likely to be able to drive themselves and some rely on rural paratransit systems. Some of the TCI investment options discussed in this report focus on providing additional and more efficient mobility options to these members of rural communities, in addition to enhancing overall access.

3.2 Passenger mobility and access

Rural areas tend to be more car-dependent than urban areas due to a lack of other mobility alternatives. On average, people in rural counties in the TCI region drive more than their urban counterparts.[18] As a result, they generate more emissions *per capita*, are more likely to be involved in vehicle crashes, and spend more on transportation, both in absolute terms, and as a share of incomes.[19]

Vehicle Miles Traveled Per Capita

Rural residents tend to travel longer distances. In 2018, total vehicle miles traveled (VMT) in TCI states reached 546 billion, of which 18% was in rural counties. People in rural TCI counties average over 10,300 VMT per capita, annually, 43 percent more than in urban TCI counties.[20] The greater VMT per person for rural residents means that there is a significant opportunity for environmental benefits from changes in their individual travel choices.

[16] EBP analysis of 2013-2017 American Community Survey 5-Year Estimates.

[17] EBP analysis of 2013-2017 American Community Survey 5-Year Estimates.

[18] EBP analysis of Highway Performance Monitoring System data.

[19] EBP analysis of HUD Location Affordability Index and 2013-2017 American Community Survey 5-Year Estimates.

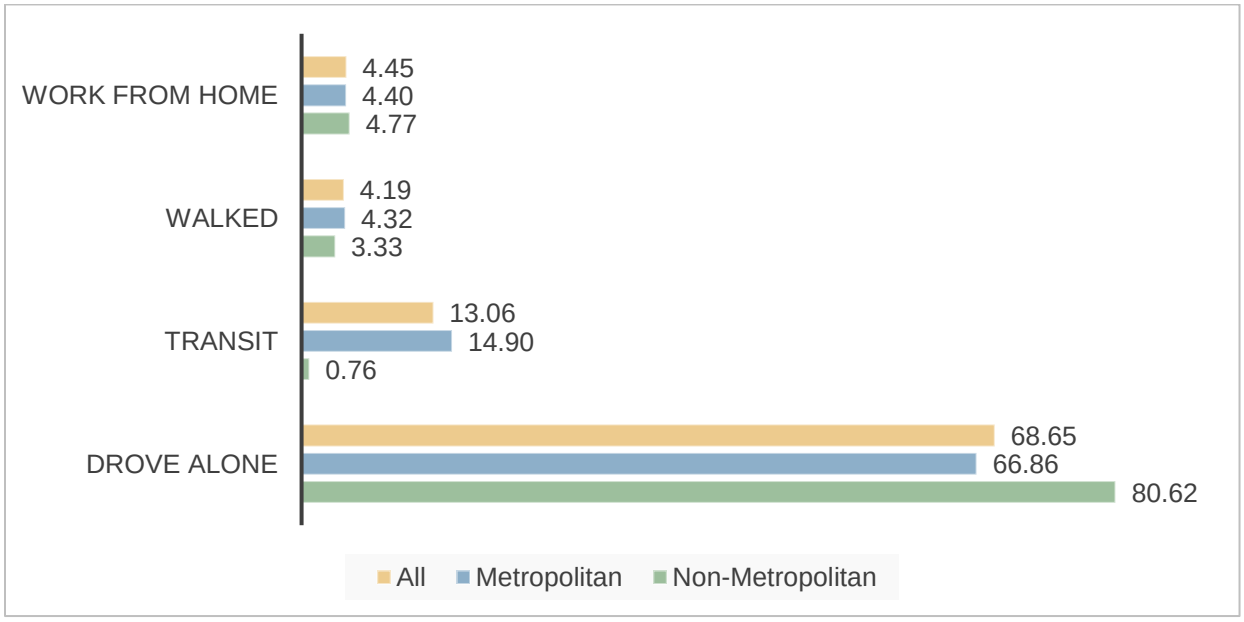
[20] Highway Performance Monitoring System.

Mode Choice

People in rural (non-metropolitan) portions of the TCI states are more likely to drive alone for their commute to work. Figure 5 illustrates the variation in mode choice for commuting between rural and non-rural counties in the TCI region. Rural residents are 21% more likely to drive alone to work than urban area commuters. The share of commuting trips served by transit in rural areas is less than one percent. Similarly, there is less walking to work in rural communities. Finally, working from home is more common in rural areas than in metropolitan areas. [21]

While driving is clearly the dominant means of travel in rural communities, there is marked variation in mode choice between states. In New York, nearly 80% of rural residents drive alone to work, compared to just shy of 50% for urban residents. This reflects the major role played by high capacity transit in New York City. On the other hand, rural residents in New Hampshire drive alone to work at slightly lower rates than urban New Hampshire commuters (79.1% versus 81.9%). Connecticut, Delaware, Maine, New Hampshire, Pennsylvania, Vermont, and Virginia show a less than 10% difference between the urban and rural drive alone share of commuting meaning that the rural-urban divide may actually be smaller than illustrated by region-wide statistics.

Figure 5 Percent of Workers by Commute Mode (2017)



Source: EBP analysis of county characteristics. 2013-2017 American Community Survey 5-Year Estimates.

Public transit availability is limited in the rural portion of the TCI region. Based on the transit services identified in the 2017 Rural Transit Factbook, approximately 4.8 million residents, or approximately half of the population in the rural (non-metropolitan) TCI counties live in sub-counties without public transit service.[22] Of these residents, approximately 2.2 million live in counties designated as "fringe", according to the classification scheme introduced in Section 3.1. These counties are adjacent to metropolitan counties, which means that public transit systems

[21] 2013-2017 American Community Survey 5-Year Estimates.

[22] Based on EBP Analysis of data collected for the 2017 Rural Transit Factbook. While the 2017 Rural Transit Factbook is the most comprehensive national inventory of rural transit systems available at this time, it is limited to transit systems that either reported to the National Transit Database or were identified by the research team at the time the Rural Transit Factbook was completed. Newer rural transit services are not included. Population estimates are from ACS 5-year estimates 2012-2017.

that connect them to metropolitan transit systems could significantly increase access to jobs and services, concentrated in metropolitan regions.

Because rural transit often has limited coverage, it is likely that a significant share of the rural TCI residents who live in sub-counties *with* some transit services, do not have access to quality public transit. Many rural residents likely live too far from rural transit routes in the area to access them without a car. In addition, rural transit often runs on limited schedules, sometimes only providing service on specific days of the week.[23]

Mode choice also interacts with vehicle availability. Workers who lack access to a vehicle, either because they cannot afford a vehicle or because they cannot drive, are more likely to use other modes. At the same time, residents with access to alternative modes may choose not to own a car. This option is much more likely to be available to urban residents. In the TCI region, 17% of households in metropolitan counties do not have access to a vehicle. In rural TCI counties, 7% of households lack access to a vehicle, which equates to about 266,000 households.[24] The lack of alternative modes in rural areas means that limited vehicle availability can be especially crippling. When alternative modes are unavailable or infeasible (including the ability to telecommute), limited vehicle availability can keep people from getting jobs.

Rural household vehicle availability varies by state. In New York, for example, 9% of rural households lack access to a vehicle, whereas in Delaware, only 4% of households lack access. In terms of magnitude, New York has the greatest number of households without vehicle access (73,900), followed by Pennsylvania (56,800) and Virginia (51,100).

Safety

Rural residents face relatively greater road safety concerns than urban residents. Because rural residents drive more (on average) than urban residents, they are more likely to be involved in a vehicular crash. Beyond this exposure effect, driving is in fact less safe on many rural roads. The average number of fatalities per 100 million VMT is 58% higher in rural areas of the TCI region than in metropolitan areas.[25] Alternative modes to driving, such as transit, are typically safer on a per mile basis and rural residents stand to benefit from these mode shifts.

The toll that road safety takes on rural economies can be shown by considering the cost of fatalities, injuries and property damage occurring in rural areas, as shown in Table 2. Just accounting for traffic fatalities occurring in the rural counties in the TCI region, the total monetized social cost exceeds $13 billion annually.[26]

Table 2: Monetized Cost per Crash

KABCO Level	Monetized Value per Crash ($2020)
Fatalities	$9,991,332
Injury - Incapacitating	$477,815
Injury – Non-Incapacitating	$130,095
Possible Injury	$66,505
Property Damage Only	$3,330

Source: U.S. Department of Transportation Benefit-Cost Analysis Guidance for Discretionary Grant Programs 2020. Guidance provides values in 2018 $s which were converted to 2020 $s.

[23] Litman, T. "Public Transit's Impact on Rural and Small Towns." 2017.

[24] 2013-2017 American Community Survey 5-Year Estimates

[25] Average between the years 2014 and 2018. Fatality Analysis Reporting System (FARS) and Highway Performance Monitoring System.

[26] EBP analysis of FARS and HPMS data, and U.S. Department of Transportation Benefit-Cost Analysis Guidance for Discretionary Grant Programs 2020. Guidance provides values in 2018 $s which were converted to 2020 $s.

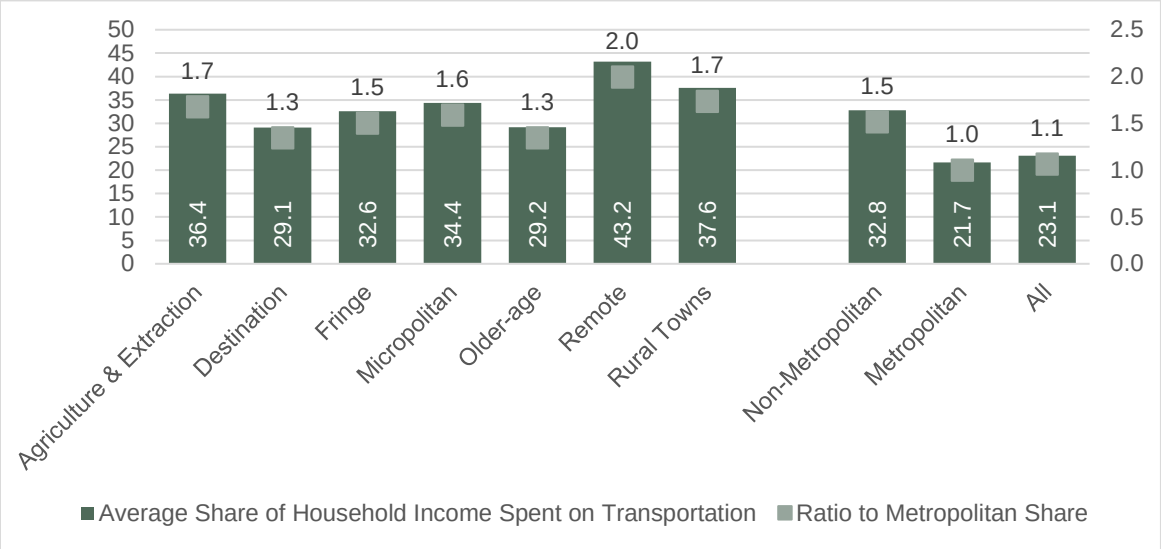
Transportation Affordability

Rural residents have greater transportation affordability concerns. The US Department of Housing and Urban Development publishes measures of transportation affordability that are location-specific, expressed as the share of household income spent on transportation. These measures were developed by first estimating travel behavior (mode share, VMT) for different locations as a function of household and built environment characteristics. From there, HUD researchers calculated fixed and variable transportation costs including automobile ownership and operation costs, as well as transit fares.[27]

The data for the TCI region shows that rural counties have an average share of household spending on transportation that is 52% higher than urban counties. This greater transportation cost burden reflects the realities of lower transit service and use and higher VMT per capita in rural areas. The affordability gap varies across rural areas types in the TCI region. On the low end, destination and older-age counties show transportation affordability that is 35% worse (i.e. the share of income spent on transportation is 35% higher) than metropolitan counties. Remote counties, on the other hand, have estimated shares of household spending on transportation that are twice as high as urban areas (Figure 6).

Overall, rural parts of the TCI region are more susceptible to economic stress associated with high transportation cost burdens than their urban counterparts. Research shows that households that cannot avoid car ownership despite affordability issues may face hard choices such as foregoing necessities (food, medical care) and purchasing and holding on to less expensive vehicles that have higher operating costs and risks of breakdowns.[28] Thus, strategies to alleviate some of the transportation cost burden can be particularly meaningful to rural residents and communities.

Figure 6 Average Share of Household Income Spent on Transportation, by Area Type



Source: EBP analysis of county characteristics: HUD Location Affordability Index.

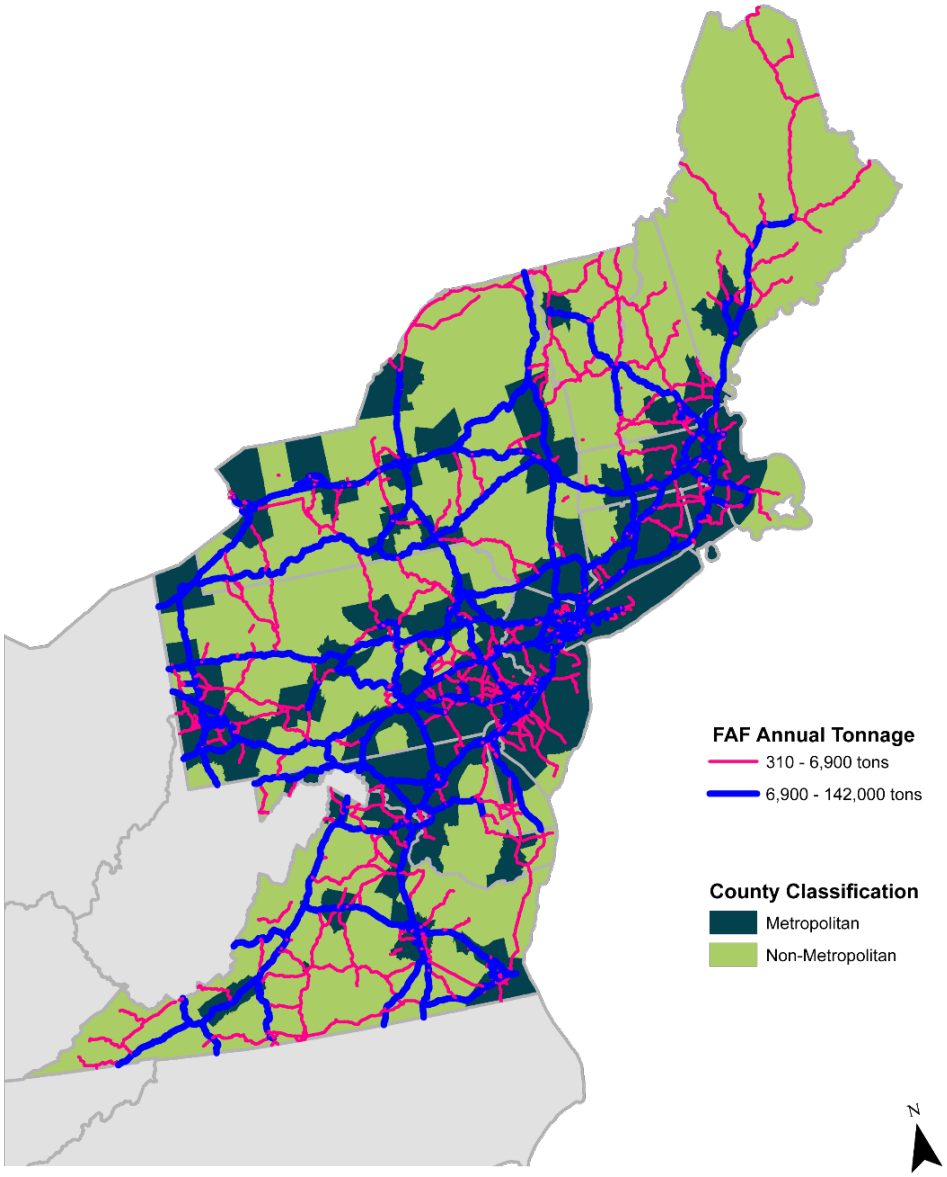
[27] HUD Exchange. LAI Data and Methodology Explanation - Version 2. https://www.hudexchange.info/programs/location-affordability-index/documentation/data-v2/#overview

[28] United Way. (2017). ALICE: The Consequences of Insufficient Household Income, Report NCR 12.19.17 Lowres. Retrieved from Dropbox.com: https://www.dropbox.com/s/rqkb78s170rr8hd/17UWALICE%20Report_NCR_12.19.17_Lowres.pdf?dl=0

3.3 Freight mobility and access

Freight transportation plays an outsized role in rural economies. Rural areas are traversed by multimodal freight corridors that are key to the economic viability of these communities and the nation as a whole. Figure 7 shows the tonnage of freight moved by truck in the TCI region.

Figure 7 Upper 50% of Tons of Freight Moved by Truck (2012)



Source: FHWA FAF4 Network Database and Flow Assignment https://ops.fhwa.dot.gov/freight/freight

Truck and rail traffic consist of a mix of local traffic that originates or is destined for rural areas and pass-through traffic that uses infrastructure in rural areas but does not end or originate within it.

- Local traffic serves to connect rural communities—and their export industries—to national and global markets, thus directly supporting local sales and income.
- Pass-through traffic is critical to ensuring the nation remains connected. For example, Norfolk Southern's Heartland Corridor provides a fast route for double-stacked rail containers moving

between the Port of Virginia and the Midwest. It has a limited number of stops along the route to minimize travel time between major markets.[29] Similarly, the Interstate highway system carries significant long-haul truck traffic. Pass-through traffic does not directly add to local economic development in the communities where it does not stop – with the exception of sales at truck stops and similar establishments serving drivers. However, pass-through truck traffic generates emissions, safety, and road preservation costs along the entirety of a corridor.

Emissions from freight traffic – particularly truck freight traffic – can have negative health impacts on rural communities. Section 3.5 discusses rural air quality.

3.4 Digital and local connectivity

The ability of people and businesses to stay connected depends on more than just transportation. Digital connectivity and sustaining vibrant local places are both important to the health, livability, and competitiveness of rural communities. The provision of broadband and the development of centers of activity with multimodal mobility options is traditionally predicated on a certain density of demand, which is overall lower in rural areas. Digital and local connectivity strategies, therefore, must be adapted to rural contexts.

Broadband

Rural parts of the TCI region confront a digital divide. In 2017, the average percent of residents without broadband in rural areas was 19.6% compared to 2.4% in metropolitan areas.[30] Figure 8 shows a map of the population without broadband access in the TCI region. A study in Pennsylvania corroborates the existence of an urban/rural broadband differential, and also finds evidence that effective actual access rates and internet speeds are significantly lower than suggested by the published data.[31]

Broadband supports economic growth, especially in low density areas.[32] The linkage between economic development and broadband is due to three factors: (1) requirements for redundant, high-speed internet for financial services firms and mission-critical technology firms, (2) the movement towards cloud computing for broader manufacturing, wholesale, retail and professional services firms and (3) trends toward more "telecommuting," "e-commerce" and even "telemedicine" – all of which depend on reliable, fast and high capacity and reasonably-priced internet service. Section 5.8 discusses how investing in rural broadband can support economic development in more detail.

The use of broadband for telework, telehealth, and online education, which can help overcome

Broadband and COVID-19

The coronavirus pandemic has highlighted the importance of universal broadband. As communities across the United States are asked to stay at home, residents of rural areas who do not have broadband speeds that allow them to work from home are disadvantaged. During the pandemic, healthcare providers are increasingly relying on telemedicine, which often relies on internet access in addition to phone communication. Even post-pandemic, telemedicine can play an important role in rural communities, where residents often live farther from healthcare facilities than their urban counterparts.

[29] Norfolk Southern. Heartland Corridor. http://www.nscorp.com/content/nscorp/en/shipping-options/corridors/heartland-corridor.html

[30] Federal Communications Commission (FCC).

[31] "Broadband Availability and Access in Rural Pennsylvania," by Sascha Meinrath, Pennsylvania State University, 2019, published by the Center for Rural Pennsylvania, a legislative agency of the Pennsylvania General Assembly. see https://www.bbcmag.com/economic-development/new-research-on-the-digital-divide-and-broadband-rsquo-s-economic-impact

[32] Kolko, J., 2012, "Broadband and local growth," *Journal of Urban Economics* 71 (1): 100-113.

some of the physical access constraints found in rural areas to work, healthcare, and education. Broadband access can play a key role in a region's resilience to disasters such as climate-related natural disasters, as well as other types of disasters such as the COVID-19 pandemic. Broadband can enable access to work, services and information when roads are closed or physical access is otherwise restricted.

As noted in some of the TCI Listening Sessions, broadband can also support dynamic on-demand shared mobility services.[33] These kinds of services can be important in rural areas that may not have the density to support traditional fixed-route public transit. Broadband can enable service providers to receive and match ride requests and users to access platforms to request and track rides.

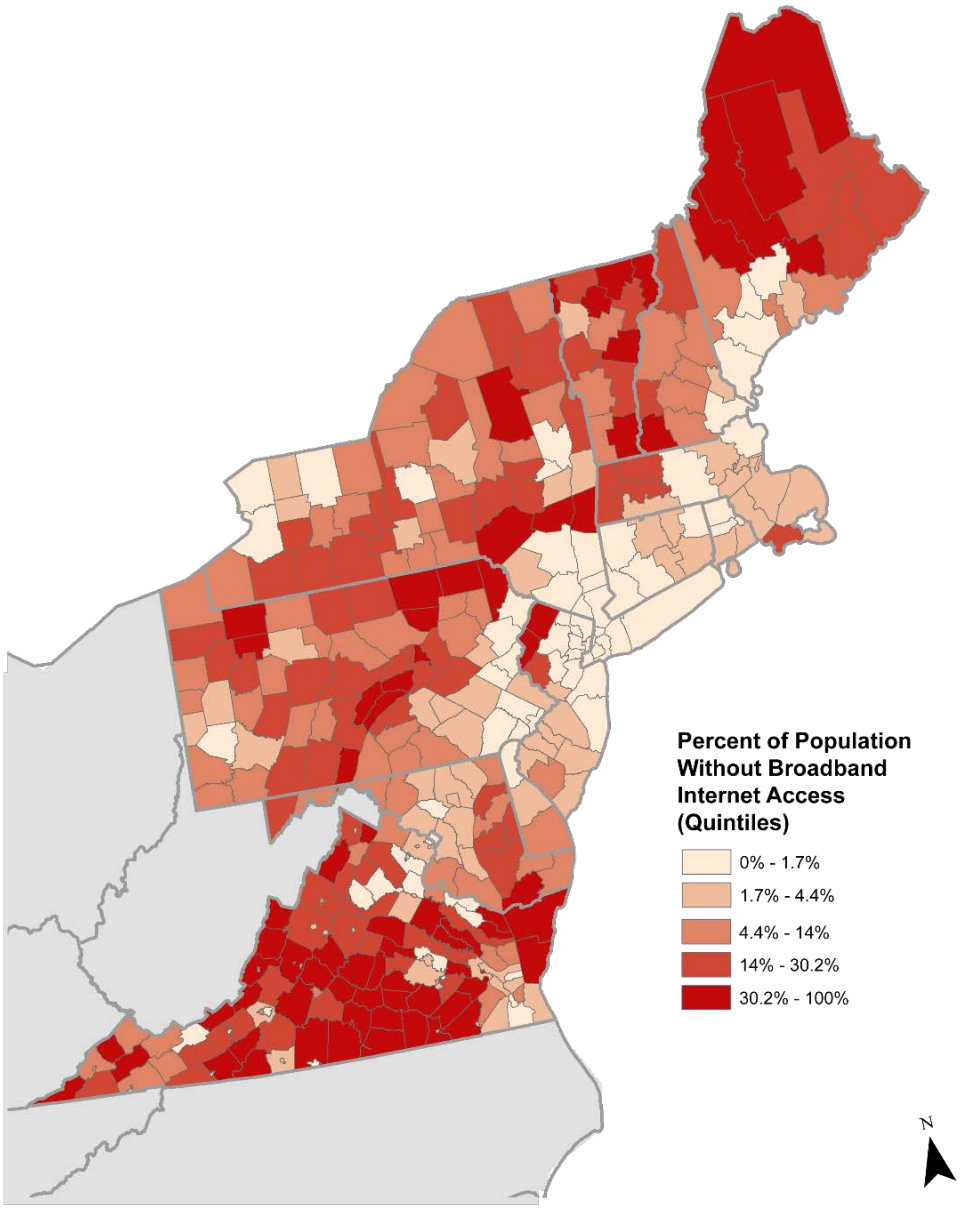
In addition to its role in improving access and resilience in rural economies, broadband has been evaluated as a mechanism to reduce VMT.[34] Telecommuting, enabled by broadband, has the potential to reduce VMT, according to recent research.[35] In general, while areas in the TCI region without broadband have higher per capita VMT, the causal relationship requires more study. Factors such as terrain challenges and low population density, which make broadband more costly to provide, are also associated with higher VMT per capita. Broadband could eliminate some trips through services such as telehealth and online education, but services such as online shopping may actually increase VMT.

[33] Franklin Regional Council of Governments. "Transportation Listening Sessions in Support of the Transportation and Climate Initiative." June 30, 2019.

[34] Washington State Department of Transportation. Impacts of VMT Reduction Strategies on Selected Areas and Groups, 2011.

[35] Shabanpour, R. et al., "Developing an Integrated Framework for Assessing Potential Impacts of Telecommuting," paper presented at the Transportation Research Board 97th Annual Meeting, Washington, D.C., January 7-11, 2018.

Figure 8 Map of Broadband Access in TCI Region



Source: Federal Communications Commission

Downtowns

Many rural communities are working towards renewal and revitalization of downtowns as centers of economic activity – an opportunity and need being tracked by the USDA Rural Information Center.[36] Vibrant activity centers can benefit rural communities by improving access to services and fostering local business development. For people who cannot or choose not to drive, town center development can reduce isolation. Town centers can also provide a "quality of life" (livability) factor for attracting young, high tech workers to rural areas – an opportunity associated

[36] Downtown Revitalization, US Dept. of Agriculture, https://www.nal.usda.gov/ric/downtown-revitalization

with the increase in tech startups and remote working environments.[37] Economically resilient town centers need to achieve and maintain a critical mass of activity and ideally also offer transportation and livability options such as walking, bicycling and transit. Recent shifts in worker and employer preferences towards more compact, connected, and multimodal town centers have made the revitalization of main streets and traditional small downtowns a focus of some rural economic developers.

3.5 Rural Air Quality

Criteria pollutants from transportation contribute to poor air quality. While rural areas generally have good air quality, topography and adjacency to urban areas, industrial zones, and power plants produces poor air quality in some rural areas.

The US Environmental Protection Agency (EPA) defines the National Ambient Air Quality Standards (NAAQS). NAAQS govern the permissible airborne concentrations of certain pollutants and pollutant precursors, known as criteria pollutants. Areas that meet the NAAQS are said to be in attainment of the standards; areas not meeting the standards are said to be in non-attainment and are compelled to take steps to improve local air quality.

In general, rural areas have better air quality than urban areas. But some rural areas do have air quality issues. For example, rural areas downwind of industrial urban areas may be in non-attainment.[38] Moreover, for many criteria pollutants, any level of exposure is unsafe.[39] Therefore, even in rural areas with relatively good air quality, reducing criteria pollutant emissions is expected to have positive health impacts.

3.6 Summary of Rural Needs

This section highlighted how rural areas in the TCI region are distinct from the region's urban centers and describes rural needs that transportation investments can address. Key findings include:

- People in rural areas of the TCI region spend more of their incomes on transportation than their urban counterparts. Investment options that reduce rural household transportation costs can be important for rural economies. In the rural TCI region, households own more vehicles and people drive more on a per capita basis than urban dwellers. This contributes to high household transportation costs and also speaks to significant opportunities for GHG reduction.
- At the same time, the rural part of the TCI region includes a disproportionate share of the region's older adults and people with disabilities. These populations are more likely to be unable to drive themselves. Public transit infrastructure is lacking in the rural TCI region, leaving non-drivers isolated. Expanding transit and shared mobility can improve access to jobs and services for non-drivers in rural areas. Local connectivity and walkability are also limited. Investing in town centers can improve livability and reduce isolation.
- Lack of broadband causes additional isolation and makes it difficult for companies to locate themselves in the rural TCI region and for residents to telework or access telehealth and e-

[37] There is a generational opportunity for rural downtowns, as millennials are being increasingly attracted to rural areas (https://www.realtor.com/news/trends/millennials), driven by "quality of life factors" (https://www.areadevelopment.com/Corporate-Consultants-Survey-Results/Q1-2020/34th-annual-corporate-survey-16th-annual-consultants-survey.shtml) that include access to community-based resources and active transportation (http://www.dot.state.mn.us/research/TS/2016/201635.pdf).

[38] Hendryx, Michael, Matthew Gurka, Melissa Ahern, and Heidi Putman. "Childhood Asthma in Rural-Urban Areas." Morgantown, WV: West Virginia Rural Health Research Center, May 2012.

[39] See: https://www.health.ny.gov/environmental/indoors/air/pmq_a.htm, and

Committee on the Medical Effects of Air Pollution. "Cardiovascular Disease and Air Pollution." United Kingdom Department of Health, 2006.

commerce. Investing in broadband can effectively expand access in the region and support economic development.

- Road safety in rural parts of the TCI region is worse than in urban areas. There are significantly more fatalities per vehicle mile traveled. Improving road safety is an important aim in rural areas.
- While air quality in rural areas tends to be better than in urban areas, major freight corridors traverse the rural part of the TCI region. Criteria pollutants from vehicular traffic, especially trucks contribute to health problems.

Given these key findings, Section 4 proposes several transportation investment options that can address these rural needs and a framework for evaluating them that measures their impacts across dimensions that are relevant for rural communities. Section 5 details how each investment option can address rural needs, citing impacts ranging from transportation cost savings to improved access to jobs and services, and improved road safety.

4. Investment Options and Evaluation Framework

This report evaluates investment options that can address the rural needs outlined in Section 3 and also help address regional TCI goals. The analysis includes solutions most commonly considered in previous research but evaluates them with respect to the rural context in the TCI region. Additionally, the report tailors some solutions, for example, public transit investment, to the rural context, and includes some less-commonly considered investment options, such as investment in broadband and freight mode shift, that are particularly relevant to the rural context.

4.1 List of Investment Options

The investment options evaluated in this paper are:

- Facilitate the adoption of electric and hybrid personal vehicles in rural areas.
- Facilitate the conversion of public fleets in rural areas to electric and hybrid vehicles.
- Facilitate electrification of freight vehicles (trucks) that pass through and serve rural areas.
- Facilitate electrification of truck stops in rural areas. Truck stop electrification consists of providing electricity at truck parking spaces to allow truck drivers to run necessary services, such as heating, air conditioning, and to power appliances without idling their engines.
- Facilitate more use of rail freight and barges in the region.
- Improve intra-regional and local public transportation and shared mobility in rural areas, including buses, shuttles, and on-demand services.
- Improve inter-regional public transportation in rural areas, including long-distance buses and trains.
- Improve broadband connectivity.
- Invest in town centers, including improved sidewalk and bike facilities and increased commercial development and services.

All of the above types of investments can be initiated through some kind of public action, though in some cases private actors also play a key role. For example, shifting truck freight to maritime and rail could be facilitated through public investment in port and intermodal facilities, but the impacts depend in part on private freight carriers.

4.2 Indicators of Benefit Value

Section 5 describes each investment option in detail and evaluates the impacts of each investment option across four dimensions:

- **GHG Emissions**: Reducing GHG emissions to prevent climate change impacts is among the stated aims of TCI. Emission reductions can be monetized to reflect the social benefits the provide, including health benefits through improved air quality.
- **Accessibility**: Transportation investment options focus on improving the transportation sector. In rural communities, improving people's ability to access to jobs and services is a critical need.
- **Economy**: As documented in Section 3, rural incomes lag behind their urban counterparts and transportation affordability is a problem in rural areas. Investment options that provide opportunities for rural economies are critical to the success of TCI. Economic evaluation of investment options considers four different types of economic impacts.

1. Spending impacts: Jobs are created in rural areas by money spent on investment, including spending to install electric vehicle charging stations, broadband facilities, operate transit networks, and build pedestrian infrastructure in town centers.
2. Cost savings impacts: Many of the suggested rural investment options enable cost savings for rural households, businesses, and public agencies. Cost savings for households improve living standards and enable more spending on other goods and services in rural economies. Cost savings for business improve profitability and viability, while cost savings for public agencies enable more funds to be diverted to address other critical rural needs.
3. Economic Development: Many of the rural investment options can support economic development by enhancing rural business and job competitiveness, attracting more private investment, labor force and employment to rural areas.
4. Social benefits: The rural investment options enable emissions reductions, safety improvements and personal time savings that can all be monetized. Where possible, the monetization of social benefits is included in the applicable category. There are also additional social benefits, such a livability and reduced social isolation that are difficult to monetize but are noted in the evaluation.

- **Health & Safety**: Exposure to vehicular crashes is also worse in the rural portion of the TCI region (see Section 3), and while air quality problems tend to concentrate more in urban areas, air quality issues can arise in rural areas, as well. Supporting health and safety in the region is an important aim.

4.3 Policy Considerations

In addition to the four performance impact dimensions, Section 5 also includes qualitative analysis of four types of policy considerations:

- **Equity**: There are two types of equity that the solutions can address: demographic equity and spatial equity. Demographic equity refers to how benefits and costs are distributed among different demographic groups, such as low-income populations, older adults, and people of color. Spatial equity refers to how benefits and costs are distributed among different places. Many of the solutions have the potential to impact both demographic and spatial equity.
- **Resilience**: Particularly in a changing climate, investment in resilience can ensure that accessibility is maintained in the aftermath of disasters and can reduce the economic costs of disasters and ensure that the economy can bounce back.
- **Rural Challenges**: Rural areas present unique challenges that do not exist in metropolitan regions. As described in Section 3, people in rural areas drive more than their urban counterparts, and lower population densities make solutions such as public transit and broadband more challenging to implement.
- **Timeline**: The expected timing for implementing and realizing the impacts of each solution varies. Understanding the expected timeline for each solution can be critical to selecting the set of solutions that are most appropriate for a particular rural region. Investment options are classified as having short, medium, or long-term return on investment.

5. Expected Benefits and Policy Considerations of Each Investment Option

Rural areas in the TCI states are not homogenous. As described in Section 3, the rural portions of the TCI region vary in important ways. This section is intended to comprehensively evaluate each investment options to assist policymakers in identifying the set of investments that can best meet the needs in their rural communities.

5.1 Facilitate the adoption of electric and hybrid personal vehicles in rural areas

There are many models of battery-electric and hybrid-electric vehicles available for purchase as personal vehicles. In the near term, policymakers interested in reducing the environmental impact of transportation in their communities could consider incentives for moving toward a clean personal vehicle fleet and removing low efficiency conventional vehicles from the roadway. There are several investment options that can encourage adoption of clean personal vehicles.

- Subsidies, rebates and tax reductions for hybrid-electric vehicle and battery-electric vehicle (BEV) purchases, including green banks to subsidize BEV or hybrid-electric vehicle purchases. Incentives programs of this type already exist, including the Efficiency Maine program, which provides up to a $2,000 instant rebate for Mainers who purchase electric vehicles.[40] This could also leverage existing car loan programs[41] to help low-income people afford the high upfront cost of a new car.
- Subsidies for installing home chargers. For example, Green Mountain Power in Vermont offers a free Level 2 (240 Volt) charging equipment with electric vehicle purchase.[42]
- Conventional vehicle scrappage rebate programs, such as the 2009 federal Car Allowance Rebate System (CARS), known as “cash for clunkers”.[43] Because rural vehicle owners tend to have older cars, which are more energy inefficient and produce more emissions, such a program may be especially effective at curbing emissions in rural areas.[44]
- Subsidies and support for construction of a charging infrastructure network in rural areas, including along highways, in town centers, and at places of work. This component is critical, as recharging availability is vital to BEV adoption.[45] Programs of this type include the development of a fast charging network along highways in Maine[46], and the Driving PA Forward program in Pennsylvania, which subsidizes Level 2 chargers for businesses across the state.[47]
- Information campaigns targeted at dispelling misconceptions of a mismatch between BEVs and rural driving and road conditions. Many electric vehicle adoption initiatives focus on providing

[40] https://www.efficiencymaine.com/ev/electric-vehicle-rebates/

[41] https://www.gsvuw.org/localvision

[42] https://greenmountainpower.com/product/home-level-2-ev-charger/

[43] https://web.archive.org/web/20091225230439/http://www.cars.gov/

[44] Based on an analysis of the National Household Travel Survey (NHTS) 2017 data for the TCI states. Federal Highway Administration. (2017). 2017 National Household Travel Survey, U.S. Department of Transportation, Washington, DC. Available online: https://nhts.ornl.gov..

[45] Ajanovic, Amela, and Reinhard Haas. “Dissemination of Electric Vehicles in Urban Areas: Major Factors for Success.” Energy 115 (2016): 1451–58.

Sierzchula, William, Sjoerd Bakker, Maat Kees, and Bert Van Wee. “The Influence of Financial Incentives and Other Socio-Economic Factors on Electric Vehicle Adoption.” Energy Policy 68 (2014): 183–94.

[46] https://www.efficiencymaine.com/at-work/electric-vehicle-supply-equipment-initiative/

[47] https://www.dep.pa.gov/Business/Air/Volkswagen/Pages/Driving-PA-Forward-Grant-and-Rebate-Awards.aspx

information to potential consumers about vehicle costs, including upfront costs and long-term cost savings; performance, including range, resilience to cold weather and snow conditions; and charging.[48]

Expected Benefits

Personal vehicle electrification will reduce energy consumption and emissions. Other expected impacts include household transportation cost savings and potential modest improvements air quality, leading to better public health. This investment option can also generate jobs installing vehicle charging infrastructure. The main challenges associated with the solution are (1) providing sufficient charging infrastructure in low-density rural communities, and (2) ensuring that policies enabling clean vehicle adoption are equitable, making adoption affordable across rural communities.

GHG Emissions. Energy and emissions impacts depend on the type of vehicles adopted. Conversion of the fleet to BEVs will produce the greatest impacts, but conversion to hybrid-electric vehicles can also lead to significant GHG reductions. Replacing 10 percent of the rural personal vehicle fleet in the TCI region with BEVs would produce a reduction of **1.4 million tons of GHG emissions** annually. Converting the same share of vehicles to hybrid-electric would reduce GHG emissions by about **700,000 tons each year**.[49] Replacing the existing fleet with high-efficiency conventional gas-powered vehicles can produce more modest impacts. GHG emissions also have a societal cost, based on estimated environmental and public health damages that can be represented in monetary terms. Based on standard federal guidance on monetization factors, the value of replacing 10 percent of personal vehicles in rural TCI counties with clean vehicles is between **$61 million** (all converted to hybrid-electric) and **$87 million** (all converted to BEVs), annually.[50]

This analysis assumes that if rural communities adopt clean vehicles, they continue to drive the same number of miles per year; any reductions in vehicle activity (e.g., VMT) would increase benefits. A detailed description of the methodology is in Appendix 1.

Economic. While there is an upfront cost to purchasing a new vehicle, over the long-run, households will save money from reduced fuel and maintenance costs by switching from conventional to BEVs and electric-hybrid vehicles. Additionally, because rural households tend to drive more and repair their vehicles more often[51], savings for rural households are actually expected to be greater than for urban households. Annual fuel cost savings for residents in the lowest density portions of the TCI region that switch from conventional to electric vehicles are expected to be $870 per driver per year, compared to about $480 for drivers in urban areas.[52]

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[48] https://www.greenenergyconsumers.org/drivegreen/electricvehicles101

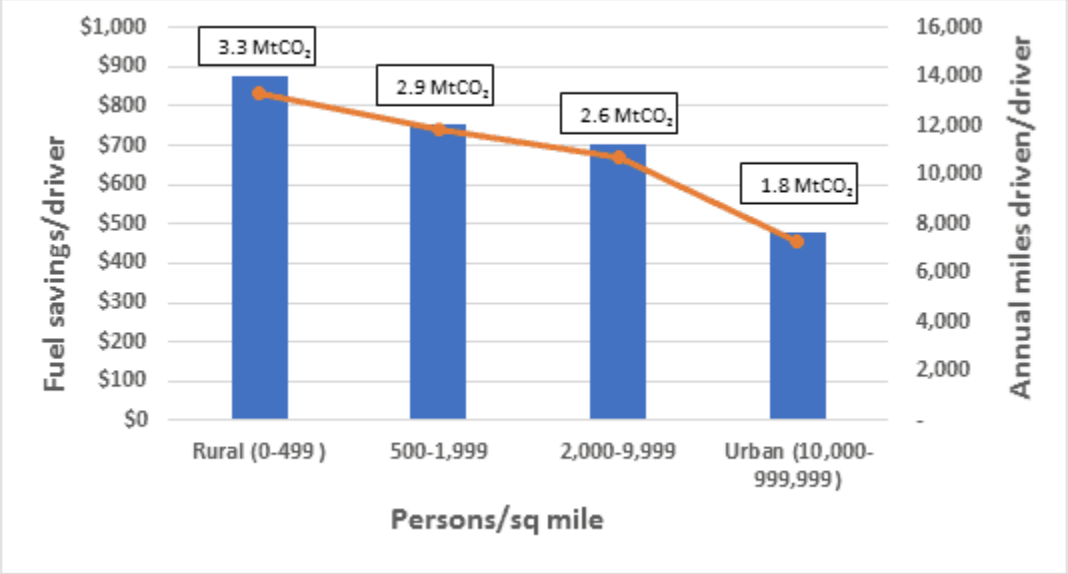
[49] EBP analysis based on USEPA's Motor Vehicle Emissions Simulator (MOVES) and HPMS data. Full description of the methodology provided in Appendix 1.

[50] Based on monetization by emission type designated in U.S. Department of Transportation Benefit-Cost Analysis Guidance for Discretionary Grant Programs 2020 and World Bank: Shadow Price of Carbon

[51] Gatti, Daniel. "Union of Concerned Scientists: Rural Drivers Have Most to Gain from Clean Vehicles." The Daily Yonder, Feb. 15, 2019.

[52] Gatti, Daniel. "Union of Concerned Scientists: Rural Drivers Have Most to Gain from Clean Vehicles." The Daily Yonder, Feb. 15, 2019.

Figure 9 Annual fuel savings, miles driven, and emissions reduction by population density in the TCI Region



Source: Union of Concerned Scientist Analysis https://www.dailyyonder.com/union-concerned-scientists-rural-drivers-can-save-clean-vehicles/2019/02/18/30455/

If 10 percent of households in rural TCI counties replace one conventional car to a BEV, the total annual household savings would be **$267 million, annually**.[53] These household savings can have a particular impact on rural economies, because while most money spent on gasoline leaves the region, households are likely to spend these savings, at least in part, on goods and services in their local economies.[54]

Investment in charging infrastructure will create new, high-paying jobs and career paths related to the installation and maintenance of the infrastructure. Jobs include engineering, site analysis, development, electrical equipment installation, certification, network testing, and site management, and have salary ranges of $45,000 to $152,000.[55] Building this infrastructure will also generate temporary construction jobs. In general, there are about 6 direct jobs generated per $1 million spent on construction.[56]

Public Health & Safety. Conversion of the personal fleet to BEVs and hybrid vehicles is expected to have positive public health impacts through the reduction in criteria pollutants, including NOx and VOCs. As shown in Table 3: Annual Criteria Pollutant Emissions Reduction from Converting 10 Percent of the Rural Personal Vehicle Fleet (tons), replacing conventional vehicles with BEVs or hybrid-electric vehicles will reduce criteria pollutants.

Table 3: Annual Criteria Pollutant Emissions Reduction from Converting 10 Percent of the Rural Personal Vehicle Fleet (tons)

	CO	NOx	SO_2	VOC	PM_{10}	$PM_{2.5}$
Emission Reduction from Conversion to BEV	3,637	242	7	40	9	8
Emission Reduction from Conversion to Hybrid	2,546	169	5	28	7	6

[53] EBP analysis based on Census population and household size, and Union of Concerned Scientist cost savings estimated (assumed $750 in annual savings per car converted).

[54] Gatti, Daniel. "Union of Concerned Scientists: Rural Drivers Have Most to Gain from Clean Vehicles." The Daily Yonder, Feb. 15, 2019.

[55] US Bureau of Labor Statistics Career Outlook Book and salaries from Zip Recruiter

[56] https://www.constructconnect.com/blog/economy/jobs-per-1-billion-infrastructure-constructionand-wall

Source: EBP analysis based on USEPA's Motor Vehicle Emissions Simulator (MOVES) and HPMS data (methodology in Appendix 1)

Finally, by introducing newer vehicles to the personal vehicle fleet, this investment option may result in modest safety improvements. Analysis of crash severity and vehicle model year shows that drivers of vehicles that are 8 to 11 years old are 19 percent more likely to be involved in a fatal crash than drivers of vehicles that are 3 years old or less. The increased risk of fatalities continues to grow with vehicle age, with drivers of vehicles 18 years or older, 71 percent more likely to be involved in fatal crashes.[57] Assuming the average vehicle age of 11 years old, replacing 10 percent of rural VMT with newer vehicles could avoid **21 fatalities** annually in the region, valued at **$213 million** in cost savings and societal benefits.[58]

Table 4 summarizes the performance impacts across the key dimensions described in Section 4.

Table 4. Performance Impacts of Clean Personal Vehicle Adoption

GHG	High	Converting 10 percent of the rural fleet in the TCI region to hybrid-electric and BEVs can reduce annual GHG emissions by 700,000 to 1.4 million tons per year, valued at $61 to $87 million in social benefits.
Accessibility	Neutral	We do not expect a fleet conversion to have meaningful impacts on destination accessibility.
Economic	Medium	Fuel and maintenance cost savings accrued to rural households are expected to be $700 to $870 per vehicle per year, which could total $267 million in the region, annually. Additionally, installing charging infrastructure will create approximately 6 jobs per $1 million invested.
Health & Safety	Medium	Conversion to clean personal vehicles will have positive impacts on air quality (See Table 3). Also, because newer cars tend to have more built-in safety features, converting 10 percent of the rural fleet in the TCI region to newer clean vehicles could eliminate 21 roadway fatalities each year.

[57] NHTSA. "How Vehicle Age and Model Year Relate to Driver Injury Severity in Fatal Crashes" August 2013. https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/811825

[58] EBP analysis based on NHTSA crash analysis, HPMS and Fatality Analysis Reporting System (FARS) fatalities per VMT, and KABCO social value from US DOT 2020 BCA Guidance.

Rural Policy Considerations

Table 5. Policy Considerations for Clean Personal Vehicle Adoption

Equity	Locations of public charging infrastructure impact spatial equity, as charging infrastructure will benefit those whose homes and destinations are near newly installed charging stations. It is important to avoid excluding certain populations. It is also important for incentive programs to help households overcome the upfront cost of a new vehicle, which can be burdensome for low-income household. Although there are increasingly affordable models available, BEVs generally cost more than conventional cars.[59] In the longer-term, adopting clean vehicles is expected to have positive equity implications, because of the lower fuel and maintenance costs.[60] Particularly for low-income rural residents, who spend a large share of their income on transportation, these cost savings can significantly improve quality of life. Policymakers should also consider negative impacts on people who work in gas stations, auto shops, and any other professions expected to be negatively impacted by reduced reliance on conventional vehicles. Programs to help these people shift into other jobs and businesses are important.
Resilience	One of the benefits of fossil fuels for vehicle fuel is their readiness: gasoline and diesel are relatively space-efficient and can be used right away. Battery power is no less readily available once stored in the battery, but long-term power outages could prevent households from being able to recharge their vehicles. At the same time, the presence of electric power in virtually all homes, business, and public buildings means it is more ubiquitously available than gasoline, which can improve resilience in some circumstances.
Rural Challenges	The sparse distribution of destinations in rural areas makes it more challenging to ensure good charging infrastructure coverage. Additionally, rural BEV adoption may be limited by perception of insufficient range. This may be largely a perception issue, as BEV cars on the market have ranges of 300 miles.[61] While not unique to rural areas, cold temperatures that are common in the northern part of the TCI region can reduce BEV range.[62] On the other hand, BEVs usually have a low center of gravity and there are models with all-wheel drive, which means they can be driven in winter weather.[63] Rural residents are also more likely to own trucks than urban residents. Currently, there are several hybrid and BEV pickup trucks, vans, and SUVs on the market. [64] Looking forward, automobile manufacturers are expected to continue to release models of all vehicle types. Two factors can make BEV and hybrid-electric vehicle adoption easier in rural areas, compared to urban areas: higher rates of home ownership[65] and prevalence of garages and driveways, both of which make at-home charging easier.
Timeline	BEV and hybrid-electric vehicles are readily available today, and some states already offer incentive programs for EV purchase. In addition, home and public charging infrastructure technology is commercially available. Therefore, policies to encourage EV adoption can be implemented quickly. However, the speed of EV adoption, and therefore the time period over which performance impacts are realized, will vary.

[59] In September 2019, the average BEV cost $54,000, while the average mid-size car cost $28,000. https://mediaroom.kbb.com/2019-11-01-Average-New-Vehicle-Prices-Up-Nearly-3-Year-Over-Year-According-to-Kelley-Blue-Book

[60] https://www.energy.gov/eere/electricvehicles/saving-fuel-and-vehicle-costs

[61] TCI Reference Case Results https://www.transportationandclimate.org/sites/default/files/20190808%20-%20TCI%20Webinar%20-%20Reference%20Case%20Results.pdf

[62] AAA. AAA Electric Vehicle Range Testing. February 2019 https://www.aaa.com/AAA/common/AAR/files/AAA-Electric-Vehicle-Range-Testing-Report.pdf

[63] https://www.greenenergyconsumers.org/drivegreen/winterdriving

[64] AAA. AAA Electric Vehicle Range Testing. February 2019 https://www.aaa.com/AAA/common/AAR/files/AAA-Electric-Vehicle-Range-Testing-Report.pdf

[65] https://www.census.gov/library/stories/2017/09/rural-home-ownership.html

Efficiency Maine Enables BEV Adoption

Rebate Program

- With a planned budget $2.25 million, Efficiency Maine offers instant rebates up to $2,000 for purchase of personal electric vehicles.
- The instant rebate can be redeemed at 48 participating car dealers across the state.

Information Hub

Purchasing an electric vehicle requires drivers to shift their understanding of how and when to fuel up – the gas station model is unlikely to be directly replicated in the electric future. The Efficiency Maine Information Hub serves as a trusted knowledge source for interested consumers, including a FAQ section covering question such as:

- How do you install a charger at home?
- What are the available vehicle types and ranges?
- What are the potential cost savings?
- Does cold weather impact performance?
- How does maintenance differ from conventional vehicles?

They also provide a directory of qualified service providers for EV charger installation.

Highway Charging Initiative

In partnership with ChargePoint, Efficiency Maine is nearing the end of Phase I of an initiative to build out a network of DC fast chargers on key travel corridors.

The Initiative, developed in coordination with the Premier of Quebec, aims to link Quebec to tourist destinations in Maine.

So far, Efficiency Maine has funded 12 DC Fast Chargers and 6 Level 2 chargers, which are operational at 6 different service plazas and supermarket parking lots.

This initiative was funded with $3.15 million from the VW Environmental Mitigation Trust.

Phase II will focus on improving local access and destination charging by increasing the number of publicly available Leve 2 chargers.

Strategic corridors prioritized for highway

https://www.efficiencymaine.com/at-work/electric-vehicle-supply-equipment-initiative/

5.2 Facilitate the conversion of public fleets in rural areas to electric and hybrid-electric vehicles

Another investment option is to convert the publicly owned fleet from conventional vehicles to BEVs and hybrid-electric vehicles. These types of programs have several implementation advantages.

- Unlike the personal fleet, many publicly owned vehicles are garaged in central places. Municipalities can build a few large-scale charging stations rather than distributing charging infrastructure around an entire region, which can take more time and resources.
- Conventional public fleets generally include heavy-duty diesel vehicles, which consume more fossil energy and emit more pollution than their light-duty counterparts. In the Northern New England region, heavy duty diesel generates 20 percent of transportation carbon emissions.[66] Therefore, replacing these vehicles with cleaner vehicles can be an especially effective strategy.
- Because public vehicles such as transit and school buses are used by many people, an electric transit bus or school bus fleet can serve as a "high profile" change, introducing the community to electric vehicle technology.[67]

Similar to programs aimed at personal electric vehicle adoption, subsidies and assistance with vehicle and charger purchases can support fleet conversion. Pilot projects, which allow public agencies to observe how electric vehicles can serve their fleet needs can be useful. In the Northern New England region, electric school bus pilots have already been introduced in Vermont, New Hampshire, and Maine.[68] Massachusetts also tested school bus electrification in three school districts across the state.[69] In Virginia, an electric vehicle fleet and chargers, as well as propane mowers were deployed in Shenandoah National Park through the Virginia Clean Cities initiative.[70]

The first all-electric transit bus fleet was launched in Seneca, SC in 2014. The municipality reported cost savings and successful, scalable implementation.[71] In the TCI region, Howard County, Maryland used a federal grant to purchase electric buses that are charged through electromagnetic induction.[72] Edison Electric Institute has published guidance on electric bus fleet electrification, including how to minimize costs and manage complex charging needs.[73] In rural areas, transit buses are often contracted operations. In these cases, electric vehicle incentives may need to be incorporated into the bidding process.

Vehicles that are commonly found in municipal- and state-owned fleets, including fleets owned by school districts, departments of public works, and police departments range from light-duty vehicles and motorcycles to transit buses, school buses, refuse trucks, heavy-duty single-unit trucks, and heavy-duty combination trucks. Converting different vehicle types will have varied impacts and implementation challenges. The following sections on impacts and policy considerations assess different fleet vehicle types.

Implementation of investments to facilitate transition of public fleets should consider vehicle usage patterns. For example, BEVs are not good match for vehicles such as snowplows, which

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[66] VEIC. "Advancing Clean Energy Investment in Northern New England." February 2019.

[67] VEIC. "Advancing Clean Energy Investment in Northern New England." February 2019.

[68] VEIC. "Advancing Clean Energy Investment in Northern New England." February 2019.

[69] Horrax, J. and Casale, M. "Lessons from Cities Pioneering Clean Transportation." October 2019.

[70] https://cleancities.energy.gov/national-parks/shenandoah

[71] Horrax, J. and Casale, M. "Lessons from Cities Pioneering Clean Transportation." October 2019.

[72] https://livegreenhoward.com/energy/transportation/

[73] Edison Electric Institute. "Preparing to Plug in Your Bus Fleet: 10 Things to Consider." December 2019.

sometimes have to operate continuously for many hours. However, many public fleet vehicles, including municipal cars, school buses, and transit vehicles are inactive at regular intervals, allowing time for charging.

Expected Benefits

Converting public fleets to electric or hybrid-electric is expected to yield GHG emissions reductions and have local air quality benefits that can improve public health. Additionally, this investment option is expected to save public agencies costs in the longer-term, due to lower fuel and maintenance costs for electric fleet vehicles. These savings can be passed on to taxpayers, including residents and business owners, who may re-spend these savings in the local economy.

GHG Emissions. Converting full-size transit buses also has a significant impact on a per-vehicle basis. Each transit bus converted to electric reduces GHG emissions by **52 tons per year**. Conversion of school buses, and refuse trucks produce GHG emissions reductions ranging from about **29 to 52 tons** per vehicle per year. While electrifying light-duty vehicles and motorcycles has a smaller impact on a per vehicle basis, these vehicle types are prevalent in public fleets across the region, including in police departments, municipal fleets, and as state and national park service vehicles. The monetized social benefit of converting municipal fleets to electric ranges from **$8,200** to **$403,000 annually for every 100 vehicles converted**. Converting vehicles to hybrid-electric produces about 30 percent of the benefit.

The conversion process also reduces energy consumed. Energy reduction can range from 1,300 MMBTU (converting 100 motorcycles) to 61,000 (converting 100 transit buses)

Table 6 shows GHG emissions and energy reduction impacts by vehicle type for conversion to electric and to hybrid-electric. We estimated annual impacts per 100 vehicles replaced, using national-average assumptions of rural public fleet activity from HPMS.

Table 6 Annual GHG Emissions and Energy Impacts per 100 Fleet Vehicles Converted

Vehicle Type	GHG Emissions Reductions (tons/year)		Monetized Social Benefit of Emissions Reductions		Reduction in Total Energy Consumed (MMBTU/year)	
	Electric	Hybrid-Electric	Electric	Hybrid-Electric	Electric	Hybrid-Electric
Light-duty Vehicle	373	260	$29,100	$20,300	4,445	3,111
Motorcycle[74]	105	-	$8,200	-	1,300	-
Transit Bus	5,180	3,620	$403,000	$282,700	61,000	42,700
School Bus	1,800	1,280	$142,900	$100,000	21,600	15,100
Refuse Truck	2,930	2,050	$228,200	$160,000	34,260	24,000

Source: EBP analysis based on USEPA's Motor Vehicle Emissions Simulator (MOVES) and HPMS data. Full description of the methodology provided in Appendix 1.

Economic. While electric fleet vehicles typically have higher upfront costs than their diesel counterparts (such as school and transit buses and refuse trucks), maintenance and fuel costs are significantly lower. Electricity costs per mile are significantly lower than diesel prices, with savings of $0.25 to $0.50 per mile.[75] And electricity prices also tend to be more stable than diesel

[74] While fully electric motorcycles are available on the mass market, hybrid-electric motorcycles are not currently available and are unlikely to be developed.

[75] Casale, M. and Mahoney, B. "Paying for Electric Buses." 2018.

prices.[76] Maintenance cost savings estimates range from $0.14 to $0.80 per mile.[77, 78] Over the lifetime of the vehicle, total costs are estimated to be lower. Without subsidies for upfront costs, lifetime cost savings for transit buses were estimated to be approximately $100,000[79], and the payback period for electric school buses in Vermont was estimated to be about 18 years.[80]

If subsidy programs reduce the upfront cost to public agencies, cost savings could be even greater. Table 7 shows estimated annual fuel and maintenance cost savings for different vehicle types. These savings, can be significant, ranging from **$3,800 per vehicle per year** for vans to **$23,000 per vehicle per year** for transit buses.

Table 7 Annual Fuel and Maintenance Cost Savings Per Electric Vehicle, Compared to Diesel Alternatives

Vehicle Type	Fuel Cost Savings	Maintenance Cost Savings
Medium Van (small transit, deliveries, etc.)	$2,100	$1,700
School Bus	$2,700	$8,200
Transit Bus	$8,000	$15,000

Sources: For medium van: Electric Vehicle Institute Electric Truck Fact Sheet and https://afdc.energy.gov/data/10309, For school bus: VEIC "Electric School Buses: Feasibility in Vermont." and Horrax, J. and Casale, M. "Lessons from Cities Pioneering Clean Transportation." and For Transit Buses: Casale, M. and Mahoney, B. "Paying for Electric Buses." 2018. Note: values depend on miles traveled and are based on assumptions about typical fleet travel patterns.

The money that local agencies save on fleet vehicles can be spent on other programs that benefit rural economies and improve quality of life.

Public Health & Safety. Finally, GHG reduction from fleet vehicle conversion can improve public health. Table 8 shows impacts of conversion on criteria pollutant emissions. Conversions from diesel vehicles, such as refuse trucks, combination trucks, and school buses tend to show the greatest benefits, especially for NOx and $PM_{2.5}$. These benefits can have marked impacts on people who use public fleet vehicles regularly, including municipal workers, such as refuse collectors, children who use school buses, and people who use rural transit, including older adults and people with disabilities.

Table 8: Annual Criteria Pollutant Emissions Reductions of Public Fleet Electrification (tons per year per 100 vehicles replaced)

Vehicle Type	CO	NOx	SO_2	VOC	PM_{10}	$PM_{2.5}$
Light-duty Vehicle	1.49	0.1	0.0025	0.04	0.004	0.003
Motorcycle	1.53	0.1	0.0007	0.06	0.004	0.004
Transit Bus	2.52	5.73	0.04	0.29	0.16	0.15
School Bus	1.1	2.02	0.02	0.11	0.06	0.05
Refuse Truck	2.97	1.73	0.02	0.12	0.06	0.05

Source: EBP analysis based on USEPA's Motor Vehicle Emissions Simulator (MOVES) and HPMS data. Full description of the methodology provided in Appendix 1.

[76] Casale, M. and Mahoney, B. "Paying for Electric Buses." 2018.

[77] Horrax, J. and Casale, M. "Lessons from Cities Pioneering Clean Transportation." October 2019.

[78] VEIC. "Electric School Buses: Feasibility in Vermont." May 2016.

[79] Horrax, J. and Casale, M. "Lessons from Cities Pioneering Clean Transportation." October 2019.

[80] VEIC. "Electric School Buses: Feasibility in Vermont." May 2016.

Table 9. Annual Performance Impacts of Public Fleet Electrification

GHG	Medium	Replacing conventional fleet vehicles with electric will reduce GHG emissions and energy consumption. Impacts per 100 vehicles replaced range from 105 to 5,180 tons of GHG emissions annually, valued at $8,000 to $403,000 in social benefits.
Accessibility	Neutral	We do not expect a fleet conversion to have meaningful impacts on destination accessibility.
Economic	High	Each converted vehicle will result in significant fuel and maintenance cost savings for the public agency. Even without subsidies to limit upfront costs, lifetime savings per transit bus converted have been estimated to total $100,000.
Health & Safety	High	Conversion of vehicles, particularly diesel vehicles, reduces air pollutants which will improve public health.

Rural Policy Considerations

Table 10. Policy Considerations for Public Vehicle Electrification

Equity	The air quality benefits from reduced roadside pollution of dangerous substances, including CO, PM, and ground ozone, would accrue across the community. The improvements will especially impact vulnerable populations, including municipal truck operators, children who ride school buses, and older adults and people with disabilities who are more likely to ride transit and wait roadside. Cost savings to public agencies may also enable money to be spent on community services that can address equity challenges or to lower taxpaying burdens.
Resilience	Electric public vehicle fleets require a reliable power supply, as these vehicles often provide essential services that cannot be interrupted. Power outages can occur as a result of natural disasters; a reliable back-up energy source is critical. At the same time, the historical stability of electricity prices compared to diesel prices, suggests that conversion to electric may improve resilience of public agencies to sudden cost increases.
Rural Challenges	Public fleet vehicles include the most expensive vehicles on the civilian market, including transit buses and refuse trucks that can cost hundreds of thousands of dollars per vehicle. Programs that reduce the high upfront costs, such as options for bulk purchasing contracts are critical. This is not expected to be a significant challenge for light-duty vehicles which are common in public fleets. Also, the lower maintenance and fuel costs for hybrid and electric vehicles may be especially enticing for resource-constrained rural public agencies.
Timeline	Rural public fleet electrification programs can be easier to implement than personal fleet electrification programs because public fleets can be purchased in bulk and tend to be garaged in central places, which makes charging infrastructure provision and operations planning simpler. However, if conventional vehicles were purchased recently, public agencies may be unwilling to purchase new vehicles.

In Virginia, Public Fleets, and Clean Ports, and Charger Maps

School Bus Programs

In Virginia's Middle Peninsula and Piedmont Regions, Virginia Clean Cities school bus programs included:

- installing diesel oxidation catalysts and engine block heaters in two school districts to reduce engine idle time
- conversion of 5 school buses to propane, saving $7,000 in fuel and maintenance costs in one year.

https://afdc.energy.gov/case/1054

Electric Car in Shenandoah Park

Electric vehicles in Shenandoah National Park

Plug-in hybrid and all-electric vehicles, and propane mowers were deployed to Shenandoah National Park as part of a Virginia Clean Cities effort. The program also installed three Level 2 chargers and produced education materials for park visitors tying the adoption of low emissions vehicles to the preservation of natural resources and habitats.

https://vacleancities.org/about/success-stories/

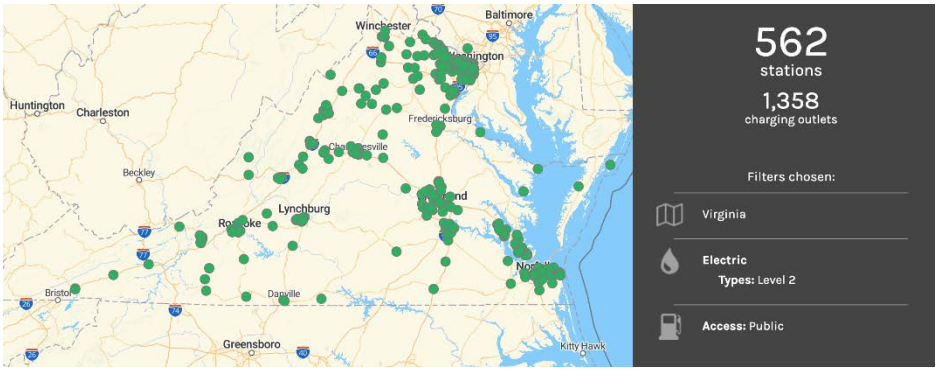
Port of Virginia Truck Drayage

The Green Operator program supported upgrade of nearly 500 dray trucks at the Port of Virginia. The program included a hotline providing information on financing drayage truck replacement. The program provided up to $20,000 incentive to purchase newer trucks and $6,000 to retrofit older trucks.

http://www.portofvirginia.com/port-of-virginia-launches-enhanced-green-operator-program-in-partnership-with-virginia-clean-cities/

Charger Map

Interactive maps help Virginians find chargers by type.



5.3 Facilitate conversion of freight vehicles that pass through and serve rural areas to electric, hybrid electric, and other high-efficiency vehicles

As with other vehicle electrification solutions, freight vehicle electrification success depends on access to vehicle charging infrastructure on local roads as well as highways. Potential solutions to incentivize freight companies to shift to BEVs and hybrid-electric vehicles are similar to those for personal vehicles: financial incentives for clean truck purchases and making charging infrastructure ubiquitous will have strong influence on freight companies converting their fleets. It must be noted, however, that freight vehicle electrification is not a near-term solution. BEV short-haul trucks are nearing financial viability, but long-haul trucks will not become cost-effective until technology improves substantially – in fact, hydrogen fuel cells may prove more viable than batteries.[81] Hybrid-electric heavy-duty vehicles are already in service in small quantities for short-haul activities, and some long-haul (e.g., Class 8) vehicles are available on the mass market.[82]

In practice, this investment option could consist of financial incentives for freight fleet conversion in the region and through investment in charging infrastructure along freight corridors to facilitate the conversion process. This investment option relies on private sector response to public investment. Also, not all freight traffic originates in the TCI region. This limits the potential impact of incentives.

Expected Benefits

When this investment option becomes more viable, it has the potential to produce significant GHG emissions reductions, with air quality improvements expected in rural areas. Given expected operating cost reductions, this investment option can reduce freight shipping costs. Insofar as some truck operators and owners are in rural areas, they can potentially gain from those costs savings.

GHG Emissions. Converting 10 percent of rural freight VMT to electric could reduce GHG emissions in the TCI region by about **1 million tons annually**. The social benefit of this emissions reduction is valued at approximately **$80 million**. The majority of the benefit comes from converting combination trucks (tractor trucks pulling trailers), as these are significant producers of GHG emissions. Table 11 shows GHG emission reduction impacts and energy savings from converting rural freight to BEVs and hybrid-electric vehicles.

Table 11 Annual GHG Emission and Energy Reductions from Converting 10% of heavy-duty freight VMT in the TCI region to BEV or hybrid

	GHG Emissions Reduction (tons)		Monetized Social Benefit of GHG Reduction		Reduction in Total Energy Consumed (MMBTU)	
VMT Type	Electric	Hybrid	Electric	Hybrid	Electric	Hybrid
Single-Unit Truck	197,400	138,100	$15,393,400	$10,775,400	2,311,800	1,618,300
Combination Truck	866,700	583,600	$65,026,041	$45,518,200	9,722,100	6,805,500

[81] https://www.freightwaves.com/news/alternatives-to-diesel-in-long-haul-trucks-still-face-big-challenges-report

[82] Examples include: https://www.hyliion.com/behind-the-wheel-of-a-class-8-hybrid-electric-and-a-fully-electric/, https://www.truckinginfo.com/329676/nikola-unveils-nikola-two-hydrogen-electric-hybrid-truck, and others. The National Renewable Energy Laboratory (NREL) continues to study the viability of such technologies. https://www.nrel.gov/transportation/commercial-vehicle-technologies.html

Economic. While many factors remain unknown, current studies indicate that the total cost of owning an **electric heavy-duty freight truck** will be less than that of a **diesel truck**. Estimates place the difference at about $0.15 to $0.25 per mile.[83] While they cost more initially, there are lifetime operating cost savings that come from a lower fuel cost and maintenance cost per ton shipped. The latter is due to fewer moving parts, less caustic and hazardous fluids, minimal high-temperature exhaust or emission systems, and lack of heavy components such as a diesel truck's engine and transmissions. The North American Council for Freight Efficiency offers a TCO (total cost of ownership) calculator for truck fleet owners to compare investment in diesel or gasoline powered baseline trucks against an equivalent battery electric alternative.[84] The average tractor-trailer truck travels around 89,000 miles/year.[85] This indicates an expected annual savings in the range of $14,350 to $22,250 per truck.

Public Health & Safety. Finally, removing diesel trucks from the road will have positive air quality impacts throughout the TCI region, particularly along freight corridors. Table 12 shows the expected reduction in criteria pollutants from converting freight VMT to electric. In addition, electric trucks are expected to be safer than conventional trucks, as they provide a lower center of gravity, and typically include more advanced technology systems to prevent and avoid collisions than conventional trucks.[86]

Table 12: Annual Criteria Pollutant Emissions Reductions from Converting 10% of Freight VMT to BEV in the TCI Region (tons per year)

VMT Type	CO	NOx	SO_2	VOC	PM_{10}	$PM_{2.5}$
Single-Unit Truck	160.8	115.8	1.6	7.5	3.9	3.6
Combination Truck	130.7	602.8	7.0	19.6	17.4	16.0

Table 13. Summary of Benefits of Freight Electrification

GHG	High	Replacing diesel single-unit and combination freight trucks with BEVs or hybrid electric vehicles is expected to significantly reduce GHG emissions. Replacing 10 percent of rural freight VMT with electric vehicles is estimated to reduce GHG emissions by 1 million tons annually.
Accessibility	Neutral	We do not expect a fleet conversion to have meaningful effects on destination accessibility.
Economic	Low	Converting freight vehicles to BEVs or hybrid electric vehicles will save freight operating costs, which may have a modest positive impact on rural economies in the TCI region.
Health & Safety	High	Electrification of trucks reduces harmful pollutants, improving air quality and public health, particularly for residents who live near freight corridors or distribution centers. New BEV and hybrid-electric trucks are also expected to have safety features that can improve rural roadway safety.

[83] https://gtgtechnologygroup.com/how-the-total-cost-of-ownership-of-electric-trucks-influences-fleet-decisions

[84] https://nacfe.org/future-technology/medium-duty-electric-trucks-cost-of-ownership/

[85] ATRI. http://truckingresearch.org/wp-content/uploads/2018/10/ATRI-Operational-Costs-of-Trucking-2018.pdf

[86] https://gtgtechnologygroup.com/how-the-total-cost-of-ownership-of-electric-trucks-influences-fleet-decisions

Rural Policy Considerations

Table 14. Policy Considerations for Freight Fleet Electrification

Equity	Populations living near truck stops, distribution centers, and freight corridors, as well as those who work at truck stops and the truck operators themselves, will benefit most from reduced air pollution. This often includes low-income communities.
Resilience	As with the other electrification policies, reliable power and charging infrastructure is critical to the adoption of electric freight vehicles.
Rural Challenges	Providing chargers along the extensive rural road and highway network is challenging. Long-haul truck operators depend on heaters to stay warm during winter downtime. Therefore, access to power at truck stops is critical for freight fleet electrification.
Timeline	Technology for widespread adoption of this solution does not exist yet. While short-haul BEV trucks may become available in the near future, long-haul trucks will likely remain conventionally fueled in the near future. Additionally, the rate of freight fleet conversion will depend on the policy implemented and the structure of vehicle purchase incentives.

Enabling Multimodal Freight Transport in Western Pennsylvania

Clean Fuels/Clean Rivers is a non-profit that supports the use of natural gas on marine corridors as a replacement for diesel fuel. (http://pgh-cleancities.org/marad/)

The Greening Locomotives Initiative supported the installation of Auxiliary Power Units on Carload Express Locomotives to reduce emissions.

http://pgh-cleancities.org/us-epa-2016/

Alternate Fuels Incentive Grant Program (AFIG)

AFIG supports replacement of older shuttles, school buses, waste-hauling trucks and other vehicles. The Pennsylvania FAST Act Corridor Infrastructure Grant is a special solicitation under AFIG for installation of alternative fuel infrastructure along Pennsylvania Interstate Highway Corridors, making $1 million in grants available for public-use chargers.

Odyssey Day

With the National Alternative Fuels Training Consortium (NAFTC) out of Morgantown, WV Pittsburgh Region Clean Cities hosts an annual “Odyssey Day” educational event to “educate the public about cleaner transportation technologies”. The event, held at Community College in Oakdale, PA, is a cross between a trade show for alternative fuel vehicles and an educational event that promotes knowledge sharing about alternative fuels.

5.4 Facilitate Rural Truck Stop Electrification for Heavy-Duty Freight Vehicles

Unlike other vehicles, heavy-duty freight vehicles tend to have long periods of extended engine idling, which produces substantial emissions. This is especially true of long-haul trucks. For safety reasons, long-haul operators are obliged by federal regulations to rest a specified number of hours for every eight- or ten-hour driving shift.[87] As a result, many long-haul operators have sleeper units onboard their vehicles and will spend at least some of non-driving time in their vehicles. In order to power lights, heaters, air conditions, and other electrical appliances, operators typically run their vehicle engines, known as engine-on idling.

Numerous state and local governments, as well as the Federal government, have taken steps to reduce engine-on idling.[88] For example, several New England states have enacted anti-idling programs, including New Hampshire's Env-A-1100 regulation that limits engine-on idling for all motor vehicles.[89] One of the more promising strategies for reducing engine-on idling is truck stop electrification (TSE).[90] TSE involves providing dedicated power to truck operators during their downtime so that they can power their electrical systems with the engine off. These systems require installing adaptors or inverters on truck units, in addition to the infrastructure required to provide the power to numerous trucks at once.

Expected Benefits

Reducing heavy-duty combination truck extended idling at truck stops along rural highways can have significant benefits for rural communities. Not only does it reduce GHG emissions, it can have significant air quality benefits for individuals who live near or work at truck stops. Additionally, constructing and installing electrification infrastructure at truck stops will create rural jobs.

GHG Emissions. Electrifying 10 percent of truck stop idling activity in the rural TCI region would produce an annual GHG emissions reduction of about **230,000 tons**, a benefit valued at **$18 million**. Total energy consumed will also be reduced by **2.5 million MMBTU**[91]

Economic. Jobs will be created to construct and install truck stop electrification infrastructure. Construction spending generates on average 6 jobs for every $1 million spent.[92] Truck stop electrification will also reduce freight transportation costs, as electricity is cheaper than diesel fuel. As in the case of freight vehicle electrification, these cost savings may have a modest positive impact on rural economies in the TCI region.

Public Health & Safety. The reduction in criteria pollutants from truck stop electrification can have significant positive impacts on public health. Table 15 shows the estimated reduction in criteria pollutants from electrifying 10 percent of rural truck stop idling activity in the TCI region.

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[87] 49 CFR Parts 385, 386, 390 et al.

[88] https://afdc.energy.gov/conserve/idle_reduction_basics.html

[89] https://www.des.nh.gov/organization/commissioner/pip/factsheets/ard/documents/ard-46.pdf

[90] https://afdc.energy.gov/conserve/idle_reduction_electrification.html

[91] While local idle reduction programs exist for smaller trucks, we assumed these are not prevalent in rural areas and only examined the effects of TSE for on-highway combination long-haul trucks. We assumed all extended idle hours to be engine-on idling, and that 10% of these hours were replaced by TSE.

[92] https://www.constructconnect.com/blog/economy/jobs-per-1-billion-infrastructure-constructionand-wall

Table 15 Annual Criteria Pollutant Reduction from Electrifying 10 Percent of Rural Truck Stop Idling Activity in the TCI Region (tons/year)

CO	NOx	SO_2	VOC	PM_{10}	$PM_{2.5}$
1,057.6	2,536.5	1.8	378.2	13.3	12.3

Table 16. Summary of Benefits of Truck Stop Electrification

GHG	Medium	Converting 10 percent of rural truck stop idling activity in the TCI region to electric will reduce GHG emissions by 230,000 tons annually, a benefit valued at $18 million.
Accessibility	Neutral	We do not expect truck stop electrification to have meaningful effects on destination accessibility.
Economic	Medium	Truck stop electrification will generate jobs in rural areas constructing and installing electrification infrastructure at truck stops. A reduction in freight costs due to truck stop electrification could have a modest positive impact on rural economies.
Health & Safety	Medium	This investment option will produce significant improvement in air quality near truck stops.

Rural Policy Considerations

Table 17. Policy Considerations for Truck Stop Electrification

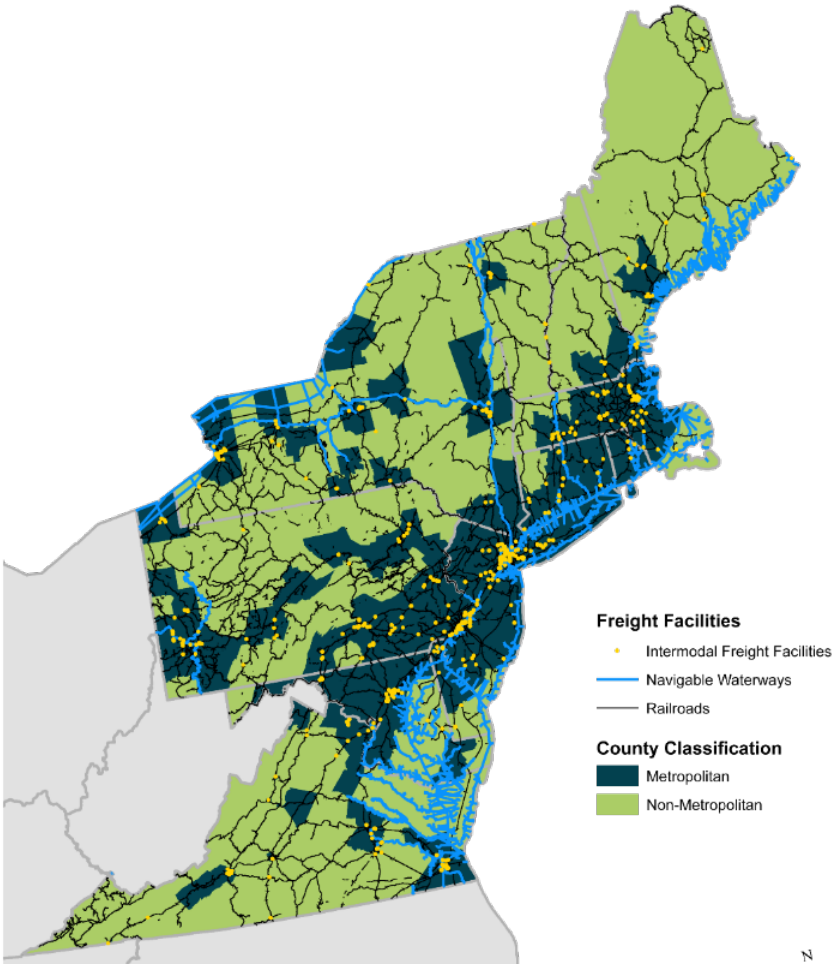
Equity	Though rural areas tend to have better than average air quality, concentrations of idling vehicles produce concentrated local effects. Populations living near truck stops, as well as those who work at truck stops and the truck operators themselves, will benefit from reduced air pollution.
Resilience	Providing electricity at truck stops, as a less expensive and more sustainable alternative to truck idling can help truck drivers wait out severe weather events.
Rural Challenges	Many remote highways do not have facilities, e.g. truck stops, and so truck stop electrification implementation would be more costly than simply upgrading existing facilities, but could be combined with efforts to expand rural electric vehicle charging infrastructure.
Timeline	Many rural interstate truck stops already have high-capacity electricity provided, so TSE implementation could be rapid. Expanding to more remote highways would require more effort and time.

5.5 Facilitate more use of barge and rail freight options in rural areas.

Trucks are the dominant mode for carrying freight in the United States and their usage is projected to grow.[93] With this growth, trucks are likely to face increasing delays and other reliability issues, especially as some sections of the Interstate Highway System—a key system for truck traffic—deteriorate and face capacity issues, especially in the Northeast.[94] Trucks are also the least energy-efficient freight mode aside from airplanes, meaning they generate more GHG emissions and ground-level air pollutants than most other freight modes. Finally, the freight shipping cost per ton-mile is much higher for truck than for rail and barge.[95]

For these reasons, shifting freight transportation from truck to rail and marine transport is a potential investment option that can benefit rural communities in the TCI region. (For purposes of this paper, "marine transport" refers to waterborne shipping by barge or ship on navigable waterways as defined in 33 CFR 329.[96]) Figure 10 shows the location of rail lines and navigable waterways in the TCI region.

Figure 10 Railroads, Navigable Waterways, and Intermodal Freight Facilities in the TCI Region



Source: Bureau of Transportation Statistics, North American Rail Lines and Navigable Waterway Lines

[93] Zhou, Y., A. Vyas, and Z. Guo, 2017, *An Evaluation of the Potential for Shifting of Freight from Truck to Rail and Its Impacts on Energy Use and GHG Emissions,* Argonne National Laboratory, https://publications.anl.gov/anlpubs/2017/08/137467.pdf

[94] National Academies of Sciences, Engineering, and Medicine, 2019, *Renewing the National Commitment to the Interstate Highway System: A Foundation for the Future,* Washington, DC: The National Academies Press, https://doi.org/10.17226/25334

[95] https://www.bts.gov/content/average-freight-revenue-ton-mile

[96] https://ecfr.io/Title-33/pt33.3.329

It is important to note that while logistics companies have recently invested heavily in truck-based freight distribution centers, rail and marine freight transport was once the norm in the US: many towns and cities were economically competitive in the past because of their accessibility by rail and by water, just as many have been similarly competitive more recently because of their proximity to major interstates. As indicated in Figure 11, many intermodal distribution facilities are on freight railroads as well as inland waterways, enabling intermodal network connectivity around the US. With the physical resources and geographic access already in place, policy changes alone may push logistics companies towards greater utilization of non-road modes.

Products that travel by both truck and rail, and thus can potentially be shifted towards more reliance on rail, include wood, metal, mineral, printing, chemical, plastic, leather, food and textile products, as well as a transportation and farm equipment.[97]

Products that travel by both truck and barge, and thus can potentially be shifted towards more reliance on barge include petroleum, metal, and chemical products, and grains, gravel, and textiles.[98]

Investment options that can encourage freight mode shift include incentives for construction and use of rail and marine facilities, as well as incentives to site distributions centers in locations that are accessible by rail or barge as well as highway.

Rural Performance Impacts

Supporting mode shift from trucking to rail or inland waterways can reduce harmful emissions, and energy consumption. It will also result in freight transportation cost savings and could spur local economic development in rural areas. It will have positive public health impacts, particularly along freight corridors.

GHG Emissions. Rail and marine are both more energy-efficient than trucks and widespread freight mode shift could help reduce GHG emissions.[99] Based on national analysis, a 4.1% reduction in truck ton-miles could lead to a 4.4% decrease in GHG emissions generated from goods movement, over a 3-year period. This reflects a 6% decrease in truck emissions and 1.6% increase in rail emissions, since they would carry more freight.[100]

Economic. Freight mode shift could also generate economic development benefits by increasing opportunities for warehousing and logistics companies to cluster around marine terminals and rail loading facilities. Some rural areas have successfully leveraged inland ports and rail terminals as part of a local economic development strategy to build clusters of logistics activity. In one review of over 180 terminals and facilities, job creation per facility ranged from 6,200 to 24,000.[101] Mode shift to rail and barge also reduces freight transportation costs. The average carrier revenue

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[97] These industries include:
- A. Industries that have modal shares for both truck and for rail that are within 50% and 150% of the national average for all commodities, when measured in terms of either weight or value. This process deletes commodities that are almost entirely shipped by one of those two modes. source: Bureau of Transportation Statistics and Freight Analysis Framework, 2018.
- B. Industries that were found to be statistically more attracted to locations with good access to truck/rail intermodal facilities. Source: "Relationship of Transportation Access and Connectivity to Local Economic Outcomes: A Statistical Analysis," Transportation Research Record #2297, by Brian Alstadt, Glen Weisbrod, and Derek Cutler. 2012.

[98] Industries that have modal shares for both marine and truck that are within 50% and 150% of the national average for all commodities, when measured in terms of either weight or value. This process deletes commodities that are almost entirely shipped by one of those two modes. source: Bureau of Transportation Statistics and Freight Analysis Framework, 2018.

[99] Maritime Administration, "America's Marine Highway," accessed March 21, 2020, https://www.maritime.dot.gov/grants/marine-highways/marine-highway

[100] Zhou et al., 2017.

[101] Chad Miller, "Job Creation Factors for Near Dock & Intermodal Facilities/Warehouse Job Creation," presentation at the 2013 Intermodal Conference, April 24-25, 2013, http://cloud.chambermaster.com/userfiles/UserFiles/chambers/9067/File/MillerChadMSWTCConferenceApril19.pdf

charge per ton-mile for truck transportation is $0.18 compared to $0.04 for rail and $0.03 for barge.[102] These shipment cost savings can be important for rural economies as agricultural and resource products are generated in rural areas, and manufacturing jobs are particularly important for rural areas.[103]

Public Health & Safety. Reducing truck VMT will improve air quality across the TCI region. Vulnerable populations could benefit most from improved air quality along freight corridors and near truck stops.[104] Additionally, freight mode shift is expected to produce road safety improvements. Railroad and marine fatalities are much less common than those involving trucks.[105,106] We estimate that one highway freight ton-mile incurs seven times more fatalities than that of rail, and 43 times more than marine (Table 18).

Table 18: Comparison of Freight-Related Fatalities by Mode (2018)

	Highway	Rail	Marine
Freight-related Fatalities	4,415	542	25
Freight Ton-Miles	2,023,456	1,674,784	489,000
Fatalities per Ton-Mile	0.002	0.0003	0.00005
Social Cost per Ton-Mile[107]	$20,946	$3,107	$491

Sources: NHTSA[108], BTS[109]

Table 19. Performance Impacts of Freight Mode Shift

GHG	Medium	Shifting freight transportation from trucks to rail and barge will reduce GHG emissions and energy consumption.
Accessibility	Neutral	One of the main advantages of trucks is that they can make “door-to-door” shipments, thereby increasing access to goods for businesses and households. Rail and marine generally lack this feature. However, shipping companies can overcome this by operating smaller trucks receive goods at rail and marine terminals/facilities and make “last mile” deliveries to warehouses or final destinations.
Economic	High	Marine terminals and rail loading facilities can generate significant numbers of jobs in rural areas.
Health & Safety	Medium	Fewer trucks would also lead to immediate health benefits from reducing harmful air pollutants. Decreasing the amount of trucks on the road could have significant safety benefits as fatalities involving trucks are much more common than those involving trains.

[102] https://www.bts.gov/content/average-freight-revenue-ton-mile

[103] https://www.usda.gov/media/blog/2017/09/12/manufacturing-relatively-more-important-rural-economy-urban-economy

[104] Mead, M Nathaniel. “Who's at risk? Gauging susceptibility to air pollutants.” Environmental health perspectives vol. 119,4 (2011): A176. doi:10.1289/ehp.119-a176a

[105] Federal Motor Carrier Safety Administration, “Large Truck and Bus Crash Facts 2017,” accessed March 19, 2020, https://www.fmcsa.dot.gov/safety/data-and-statistics/large-truck-and-bus-crash-facts-2017

[106] Federal Railroad Administration, “Grade Crossing Inventory and General Trespassing Statistics,” accessed March 19, 2020, https://safetydata.fra.dot.gov/OfficeofSafety/publicsite/Query/AccidentByRegionStateCounty.aspx

[107] The social cost of a fatality uses the 2020 USDOT Benefit-Cost Analysis Guidance cited elsewhere in this report.

[108] https://www.nhtsa.gov/press-releases/roadway-fatalities-2018-fars

[109] https://www.bts.gov/us-ton-miles-freight

Rural Policy Considerations

Table 20. Policy Considerations for Freight Mode Shift

Equity	Some populations would benefit more from freight mode shift than others. Communities located near highways and truck stops would likely benefit most from reduced truck traffic and associated emissions reductions. However, communities located along rail lines would be exposed to more emissions. Additionally, some rural communities could benefit from job generation at new intermodal facilities. However, those currently working as truck drivers or at truck stops would be negatively impacted, particularly in areas that are not near rail lines or inland waterways.
Resilience	Trucks are susceptible to road closures and detours caused by extreme weather events. Marine shipping faces fewer disruptions, although even marine shipping can face operational disruptions during extreme weather events that cause storm surges, flash floods, and wind gusts.[110] Diversifying freight traffic across modes can improve the resiliency of supply chains.
Rural Challenges	Shifting freight from trucks to other modes could be challenging in rural areas because warehouses and final destinations are often dispersed. This gives trucks an advantage over rail and marine since they can make door-to-door shipments.
Timeline	Changes to supply chains and industry practices can be slow, particularly if they require infrastructure improvements. However, if highway capacity issues and extreme weather events make truck shipments more costly in the next several years, companies could respond relatively soon by shifting to more reliable and efficient modes.

5.6 Improve intra-regional and local rural public transportation and shared mobility options in rural areas

Intra-regional and local public transportation and shared mobility in rural areas can include several types of service:

- Fixed route bus and shuttle service, which can provide service within town centers, between town centers, and connecting town centers to surrounding homes and destinations
- On-demand microtransit and shared mobility services, such as shuttles, vans, and shared ridesourcing vehicles, which can accommodate lower density of demand, compared to fixed route service.
- Carpooling programs, including formal and informal programs.

Investing in intra-regional and local rural public transportation can include both investing in expanded coverage and investing in improved service quality. Examples of investment opportunities include:

- increasing the span of service to cover more days or longer hours;
- expanding coverage to new areas that currently do not have service;
- providing more frequent service;
- providing better service information;

[110] Christodoulou, A., P. Christidis, and H. Demirel, 2019, "Sea-level rise in ports: a wider focus on impacts," *Maritime Economics & Logistics* 21, 482-496, https://doi.org/10.1057/s41278-018-0114-z

- improving service convenience, for example through easy-to-use on-demand service and carpooling programs;
- improving non-emergency medical transport

Non-Emergency Medical Transit Services

In the Scranton and Danville, PA areas in 2018, Geisinger Health System piloted a transit services program. The program is primarily focused on transporting people to medical visits, but also provides transportation for food, social service, and pharmacy needs.

Sylvester, J. "Geisinger rolling out transportation for those without a ride." April 8, 2018.
https://www.dailyitem.com/news/local_news/geisinger-rolling-out-transportation-for-those-without-a-ride/article_a474797c-6334-5e19-a84e-ad664c0991a3.html

While transit service is lacking in coverage and quality in many rural communities in the TCI region, some communities see its potential. For example, with support from the Going Places Network and the Maine Community Foundation, Presque Isle, Maine has developed a successful community bus services, and supporters suggest that TCI can fund similar projects.[111] In the Upper Valley region in New Hampshire and Vermont, Advance Transit provides free transit to improve access to jobs and services and reduce traffic in village centers in the region.[112]

Expected Benefits

Investing in rural public transit is expected to reduce GHG emissions and energy use, improve accessibility, and save rural households money. Additionally, this investment option is expected to improve rural air quality and rural road safety.

GHG Emission. Shifting vehicle trips to public transit and share mobility options, increases vehicle occupancy in rural areas, reducing VMT and GHG emissions. Each $1 million investment in rural transit, resulting in approximately 100,000 new public transit trips will result in a reduction of approximately **142 tons of GHG emissions, annually**.[113] The shift will also reduce total energy consumed by an estimated 1.9 MMBTU annually.

Accessibility. Improving public transit and shared mobility enables people in rural areas to access destinations without cars. This is especially beneficial to people who cannot or choose not to drive, including older adults, youth, and people with disabilities. There are 600,000 people with disabilities and 1.1 million people over 60 who are currently without transit service in the TCI region. [114] Expanding service would significantly increase access to jobs and services for these populations.

Economic. Expanding job access improves business efficiency, which is good for rural economies. Additionally, providing rural residents with transit and shared mobility alternatives is expected to lower household transportation costs. As described in Section 3, rural residents spend a significant portion of their incomes on transportation (on average 33 percent). Transit is typically a much more affordable option than driving. For households that are able to give up an automobile, the savings for an individual who replaces car trips with transit are approximately

[111] Thill, David. "Small cities could boost transit options with transportation climate funds." March, 9 2020. https://energynews.us/2020/03/09/northeast/small-cities-could-boost-transit-options-with-transportation-climate-funds/

[112] https://advancetransit.com/about/

[113] EBP analysis of NTD data, APTA summary of transit on-board surveys, and modeling using USEPA's Motor Vehicle Emissions Simulator (MOVES). More detail in Appendix 1.

[114] ACS 5-year estimates 2012-2017

$9,797 annually.[115] Even for those who cannot give up a car, shifting a trip from driving to transit saves approximately $2.12, on a per trip basis.[116] A $1 million investment would yield at least **$171,000 in total rural household transportation savings**, excluding any savings from a reduction in car ownership. Households that reduce their transportation spending tend to invest that money in other parts of the economy, creating follow-on effects in rural economies.

Public Health & Safety. This investment option is expected to have modest positive impacts on air quality. Conventional transit buses produce more criteria pollutants than light-duty vehicles. While the increase in overall vehicle occupancy counteracts this, it diminishes the positive impacts. If this investment option were combined with transit vehicle electrification, it could produce significant reductions in criteria pollutants.

The reduction in total rural VMT is expected to have a positive impact on roadway safety. For every 100,000 new rural transit trips, our analysis estimates a reduction in rural VMT of approximately 600,000 (this accounts for additional transit VMT and the fact that not all new transit trips shift from single-occupancy vehicles). Just accounting for the expected reduction in roadway fatalities, the safety benefit is valued at **$86,600** for every 100,000 additional transit trips.[117]

Finally, improving rural transit service can play a key role in helping individuals access non-emergency medical services, which will have positive health and economic outcomes. This is particularly important for older adults and people with disabilities residents who cannot or should not drive, as well as the significant portion of the rural population living in households with more adults than vehicles.

Table 21. Performance Impacts of Intra-Regional and Local Public Transportation

GHG	Medium	Each $1 million investment, resulting in approximately 100,000 new public transit trips will result in a reduction of approximately 142 tons of GHG emissions.
Accessibility	High	Access to jobs and services is more limited in rural areas, particularly for people who cannot drive. Public transit and shared mobility can provide key access to jobs and services, especially for youth, older adults, and people with disabilities.
Economic	Medium	Households that can shift trips from driving to transit and shared mobility are expected to save money. For every 100,000 new transit trips, household travel savings are estimated to be at least $171,000. Additionally, improved access to jobs can enhance business efficiency, and better access to non-emergency medical services reduces rural medical costs.
Health & Safety	Medium	Reducing VMT by replacing drive alone trips with higher occupancy transit and shared mobility trips reduces vehicle crashes. Improved access to non-emergency medical services is expected to improve health outcomes.

[115] APTA Transit Savings Report, June 2017.

[116] Based on EBP analysis of AAA Your Driving Costs 2019 report and National Transit Database 2018

[117] Based on EBP analysis of APTA on-board survey (for trip shifting behavior), FARS and HPMS data (road safety statistics), and US DOT BCA 2020 Guidance (social cost of fatalities).

Rural Policy Considerations

Table 22. Policy Considerations for Intra-Regional and Local Public Transportation

Equity	High-quality transit service allows non-drivers or those who would prefer not to drive – including older adults, youth, and people with disabilities – to reach jobs and services. Low-income people, who disproportionately spend on transportation, can benefit from cost savings compared to driving.
Resilience	Resilience includes many facets. Expanding transportation options can improve resilience to some events and circumstances. Providing rural communities with mode alternatives to driving a personal vehicle improves resilience.
Rural Challenges	Because of low population and job density in rural areas, rural public transportation tends to have a high cost per rider and low occupancy. Coupling these services with investment in intercity public transit and with investment in town centers could make them more effective. Negative attitudes toward transit can reduce the effectiveness of this investment option. However, polling in rural Massachusetts showed positive sentiment toward transit.[118]
Timeline	Turnkey solutions for on-demand services can be implemented in the short-term. More traditional shuttle or bus services may take a bit longer but can still be implemented fairly quickly.

5.7 Improve inter-regional transit in rural areas

Inter-regional transit services include:

- inter-regional buses, including services such as Peter Pan and Greyhound.
- inter-regional rail, including Amtrak routes that serve rural regions in the Northeast such as: the Vermonter, Adirondack, Maple Leaf and Lakeshore Limited.

While several Amtrak routes serve rural areas in the TCI region, they currently provide limited service, particularly in rural areas. For example, the Maple Leaf, which runs from New York to Toronto with stops in Upstate New York runs just one train in each direction daily, as does the Vermonter, which runs from Washington, D.C. to northern Vermont, with stops in Western Massachusetts and throughout Vermont. More frequent service on existing routes could enable people in rural communities to make inter-regional round trips within a single day, which is impossible with limited schedules. Some regions are not connected by Amtrak routes and instead rely on bus services, which are typically slower than train services and are also have infrequent services to many rural destinations.

In Virginia, the Virginia Breeze inter-city bus service was developed by the state Department of Rail and Public Transportation to fill gaps in existing inter-city bus service and provide access to underserved population. Their first route, connecting Washington, D.C to the New River and Shenandoah Valleys had 19,300 riders in its first year of operation. Fares are subsidized to maintain affordability for passengers. However, the service has proved productive and efficient, with a farebox recovery ratio of 81 percent.

Source: Virginia Breeze Fact Sheet 2019. *https://virginiabreeze.org/wp-content/uploads/sites/2/2019/10/virginia-breeze-fact-sheet.pdf*

VIRGINIA BREEZE

[118] New Bridge Strategies and FM3 Research on behalf of the Nature Conservancy (September 2019), "Small Town & Rural Voters' Views of Investments Related to the Transportation and Climate Initiative a Clean Transportation Fund in the Northeast & Mid-Atlantic."

This investment option could include developing policy incentives to increase Amtrak route frequency and provide additional inter-city bus services to connect rural areas. Programs could also subsidize inter-city bus and rail fares, making them more attractive to rural residents.

Expected Benefits

Increasing long-distance train and bus service can improve access to many specialty destinations (e.g., business meetings, doctors and hospitals, certain stores, airports) for those that cannot or prefer not to drive. Some people may also choose to use these modes for long-distance commutes into urban job centers.

GHG Emissions. Converting driving trips to high occupancy modes (bus and rail) reduces GHG emissions. Replacing 100,000 100-mile driving trips with long-distance bus trips saves approximately **2,600 tons** of GHG emissions, producing a social benefit of approximately **$210,000**.[119] It will also reduce total energy consumed by 35 MMBTU.

Accessibility. Some destinations require rural residents to travel long distances. In particular, specialty healthcare, airports, and business meetings often require long distance intercity travel. The 266,000 rural households in the TCI counties that lack access to a car will benefit.[120] As will non-drivers, including older adults and people with disabilities, population groups that are more highly concentrated in the rural areas of the TCI region than in urban centers.[121]

Economic. Improved access has a positive impact on rural economies. In addition, it could support rural tourism. Also, this investment option is expected to save households travel costs. While train fares are often comparable to per mile driving costs, bus fares tend to be significantly cheaper. Bus fares vary. A 100-mile bus trip can be $5 to $12 cheaper than driving the same distance.[122] Finally, compared to driving, taking public transit for long commutes allows workers to be productive during their commute time.

Health & Safety. Shifting long distance trips from car to bus and rail will reduce criteria pollutants, improving air quality in the rural TCI region. Additionally, the reduction in VMT is expected to improve road safety. Shifting 100,000 100-mile trips from driving to inter-city bus would reduce vehicle crash fatalities and other crashes. The reduction in fatalities would yield $1.2 million in social benefits.[123]

Table 23. Performance Impacts of inter-regional transit

GHG	Medium	Converting driving trips to high occupancy modes (bus and rail) reduces GHG emissions. Replacing 100,000 100-mile driving trips with long-distance bus trips saves approximately 2,600 tons of GHG emissions.
Accessibility	Medium	Particularly when coupled with local and intra-regional public transit, inter-regional transit increases access to destinations for people who cannot or choose not to drive. In particular, it can help people reach specialty destination such as business meetings, healthcare, and airports.
Economic	Medium	This investment option can support tourism, reduce household transportation costs, and enable productive use of travel time for long trips.
Health & Safety	Medium	The reduction in VMT from train and bus trips that shift away from driving results in fewer vehicular crashes and reduction in air pollutants.

[119] EBP analysis based on EPA MOVES model, and US DOT BCA Guidance and World Bank carbon and criteria pollutant valuation.

[120] 2013-2017 American Community Survey 5-Year Estimates

[121] See figures in Section 3.

[122] AAA cost per driving and wander.com for bus and train fares

[123] Based on FARS and HPMS data (road safety statistics), and US DOT BCA 2020 Guidance (social cost of fatalities).

Rural Policy Considerations

Table 24 Policy Considerations for Inter-regional Transit

Equity	High-quality transit service allows non-drivers or those who would prefer not to drive – including older adults, youth, and people with disabilities – to reach destinations in other regions. However, the benefits of inter-regional transit are limited spatially to the populations served by long-distance transit. Good connections to local and intra-regional transit can ensure that more of the rural population is able to access long-distance transit.
Resilience	Alternatives to driving improve resilience at the inter-regional scale, as people are able to make trips even if roads or airports are disrupted.
Rural Challenges	Because of low population and job density in rural areas, it is difficult to justify increased long-distance services, especially train service, which is a high capacity mode.
Timeline	Increasing service frequency on existing routes can be implemented in the short-term. New bus routes can also be added fairly quickly. New train routes require a long planning and development process.

5.8 Improve Rural Broadband

In 2017, the average percent of residents without broadband in rural areas was 19.6% compared to 2.4% in metropolitan areas.[124] A map of broadband availability is included in Section 3.

This investment option can include programs and incentive structures that increase broadband proliferation in rural areas. In Pennsylvania, the Northwest Commission is using state funding to deploy wireless technology for broadband connectivity to underserved areas.[125] Other programs combine broadband with town center development. This includes the "Cool & Connected" initiative of the Environmental Protection Agency to help communities leverage broadband to "create walkable, connected, economically vibrant main streets and small-town neighborhoods that improve human health and the environment."[126]

Expected Benefits

Improved broadband availability in rural areas is expected to promote local economic development, enabling businesses to locate in rural areas. Additionally, it enables telework, telehealth, and e-commerce. The coronavirus pandemic has demonstrated the importance of access to broadband to enable remote work.

GHG Emissions. Broadband deployment can result in modest VMT reduction. In some industries, broadband enables remote work. When more employees "telecommute," it may help reduce vehicle miles traveled and associated greenhouse gas emissions.[127, 128] Broadband can also support an increase in the number of local employers in rural areas, which can reduce long distance commutes. This may further reduce rural VMT.

Accessibility. High quality internet allows people to access distance learning, telehealth, and telecommuting. This effectively improves their access to education, healthcare, and employment. High quality internet and mobile broadband like 4G LTE also enables ride requests for demand-responsive transportation services and the dissemination of information about public transit (e.g.,

[124] Federal Communications Commission (FCC).

[125] https://pugglieseassociates.com/northwest-commission-receives-funding-expand-broadband-connectivity-rural-pa/

[126] Environmental Protection Agency (EPA). Cool & Connected. https://www.epa.gov/smartgrowth/cool-connected

[127] Shabanpour, R., et al., 2018, "Analysis of telecommuting behavior and impacts on travel demand and the environment," *Transportation Research Part D: Transport and Environment* 62: 563-576, https://doi.org/10.1016/j.trd.2018.04.003

[128] Patricia Mokhtarian, "Biggest Steps to Decarbonization: Is Telecommuting the Answer?" presentation at the 99th Annual Transportation Research Board Meeting, January 13, 2020.

schedule or route changes). These features can greatly enhance personal freedom for those who cannot drive. Broadband is also expected to facilitate more businesses locating in rural areas (see section on economic impacts). This is expected to increase the number and type of accessible jobs in rural areas.

Economic. Studies have shown that broadband is a critical pre-condition for business site selection for many business types. Broadband supports marketing, data management, and supply chain management[129] and having adequate broadband can make businesses more efficient, productive, and competitive.[130] Additionally, in rural areas, telecommuting can overcome transportation access limitations to open up new high-tech jobs for rural workers, while e-commerce can enable new warehousing and distribution centers at rural sites.

There is particularly strong evidence of the opportunity for rural communities to gain from current trends towards more remote work enabled by broadband service. A recent study found that teleworking and telecommuting positively impact median household income at the local level and can spur further economic growth in surrounding areas. However, that depends on the availability of supporting broadband service.[131] Nationally, economic programs such as the Rural Innovation Initiative are now assisting rural communities in becoming tech hubs; however, a community must have high speed broadband service as a prerequisite for participation.[132]

There is empirical evidence demonstrating the relationship of broadband and economic prosperity. A study followed non-metro counties that did not have broadband and distinguished two groups: those that later received broadband and achieved relatively high (>60%) rates of use and those that did not. Comparing economic trends between these two groups showed that broadband adoption is associated with higher subsequent income growth and reduced subsequent unemployment. The differences were statistically significant and amounted to a 1.4% increase in countywide income.[133] This type of finding was also corroborated in an international study of the World Bank, which found that a 10% increase in high speed broadband penetration was linked to a 1.38% increase in GDP among the economies of developed nations.[134]

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[129] *Access in Appalachia Concepts and Methodologies – Final Report*, (Forthcoming), Appalachian Regional Commission.

[130] The Federal Communications Commission considers adequate broadband to have speeds of 25 mbps download / 3 mbps upload.

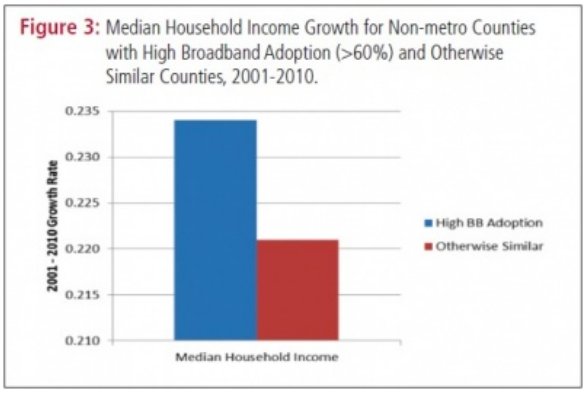
[131] "21st Century Economic Development: Telework and Its Impact on Local Income," Regional Science Policy and Practice, March 2018, by Roberto Gallardo and. Brian Whitacre, Oklahoma State University.

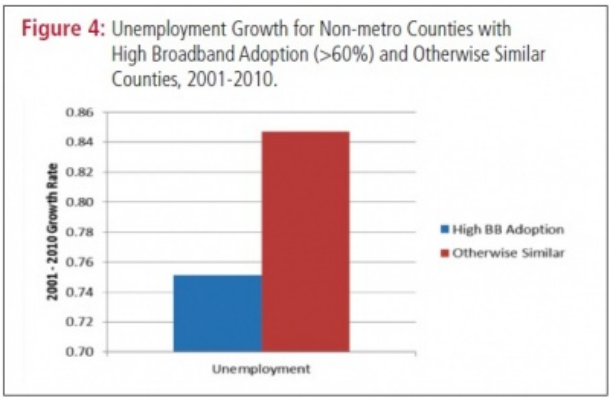
[132] Reversing the rural brain drain with remote working," *Curbed*, Feb 12, 2019. https://www.curbed.com/2019/2/12/18221421/startup-remote-working-rural-coworking

[133] "Broadband's Contribution to Economic Health in Rural Areas", Issue 64, *Research & Policy Brief*, February 2015, by Brian Whitacre, Oklahoma State University, Roberto Gallardo, Mississippi State University, Sharon Strover, University of Texas https://cardi.cals.cornell.edu/publications/research-policy-briefs/broadband's-contribution-economic-health-rural-areas/

[134] "The Economic Case for Bringing Broadband to the Rural US", June 4, 2018, by Wolfgang Bock , Derek Kennedy , Maikel Wilms , Simon Bamberger , and Sam Fatoohi, Boston Consulting Group. https://www.bcg.com/en-us/publications/2018/economic-case-bringing-broadband-rural-united-states.aspx

Figure 11 Broadband Impact on Income and Unemployment Change





Source: "Broadband's Contribution to Economic Health in Rural Areas", Issue 64, Research & Policy Brief, February 2015, by Brian Whitacre, Oklahoma State University, Roberto Gallardo, Mississippi State University, Sharon Strover, University of Texas https://cardi.cals.cornell.edu/publications/research-policy-briefs/broadband's-contribution-economic-health-rural-areas/

Public Health & Safety. There is also evidence that rural broadband improvement brings health benefits. A recent medical study found evidence that "inadequate broadband infrastructure in rural areas prevents telemedicine from mitigating the barriers to care associated with physician shortages."[135] Additionally, VMT reduction from telecommuting is expected to reduce vehicular crashes and criteria pollutants, both contributing to public health improvements.

Table 25. Performance Impacts of Improved Broadband

GHG	Low	Greater broadband availability can lead to a small reduction in VMT and associated GHG emissions by enabling telecommuting.
Accessibility	Medium	High quality internet allows people to access key services and jobs through distance learning, telehealth, and telecommuting. Additionally, broadband is expected to facilitate the location of many types of businesses in rural areas. This will increase rural access to jobs.
Economic	High	Many companies require high quality internet to conduct business and remain competitive. Business functions that rely especially on broadband include marketing, data management, supply chain management, and cloud computing. Having reliable broadband can help regions attract new businesses and encourage entrepreneurship, both of which help create jobs and generate tax revenue.[136]
Health & Safety	Low	Telemedicine improves access to healthcare in rural areas. Reduced VMT will also bring public health and road safety improvements.

[135] "The Limitations of Poor Broadband Internet Access for Telemedicine Use in Rural America: An Observational Study," *Annals of Internal Medicine*, Sept. 2019, by Coleman Drake, Yuehan Zhang, Krisda. Chaiyachati, Daniel Polsky. Summarized in https://www.fiercehealthcare.com/tech/poor-broadband-access-rural-areas-limits-telemedicine-use-study

[136] Economic Development Research Group, Michael Baker International, and Renaissance Planning, 2017, *Lynchburg Regional Connectivity Study,* http://oipi.virginia.gov/documents/lynchburg-connectivity-final-report-3-2-17.pdf

Rural Policy Considerations

Table 26. Policy Considerations for Improved Broadband

Equity	The effectiveness of broadband depends on how evenly it is deployed. If only large, well-resourced businesses in urban areas are connected, smaller businesses in rural areas could struggle to compete. At a household level, steps should be taken to ensure that broadband is affordable enough to benefit more than just high earners. Today, high-income households are more likely to use internet at home than low-income households.[137] Broadband should also be equally available to industries concentrated in rural areas like agriculture and resource extraction. Realizing the benefits of broadband requires familiarity with technology. Technology training can transfer benefits to older adults and others with limited experience with technologies such as computers and smartphones.
Resilience	Rural areas without broadband are disproportionately impacted by events that disrupt mobility. These include natural disasters and public health emergencies like the coronavirus pandemic. During these disruptions, workers with broadband access can more easily telecommute, access telehealth and online education, and purchase goods online, than those without.
Rural Challenges	Deploying broadband in rural areas is less economical than in urban areas because of the greater distances between homes and businesses.[138] There is also less demand in rural areas, given their low-density population and employment, meaning that telecommunications providers may have a difficult time delivering service profitably. This is why some smaller municipalities have launched publicly owned broadband networks, although state laws have made this more difficult in recent years.
Timeline	Rural broadband deployment can take longer to deploy than urban broadband because of higher costs and sometimes challenging terrain. Deployment could be accelerated under a proposal to co-locate wireless facilities with towers managed by the Department of the Interior.[139] This approach could limit the social and political impact of deployment in communities by limiting the amount of private property acquisition.

5.9 Invest in Small Town Centers

Focusing on town centers has long been an economic development strategy, especially in rural areas. So-called “Main Street revitalization” efforts place an emphasis on small commercial corridors that have the infrastructure to support clustered business activity—i.e., commercial space, utilities, sidewalks, parking—but have seen disinvestment with the rise of low-density commercial development designed for the automobile.[140] Programs include the National Trust’s “Main Street Program”[141] and the Federal Reserve’s “Main Street Lending Program.”[142] The EPA’s “Cool & Connected” program has several programs in TCI states, including a program in Millinocket, ME, working to revitalize a paper mill and a program in Curwensville, PA, focused on developing a coworking space. While the programs focus on leveraging broadband, communities also receive planning and technical assistance in order to best leverage broadband to support town center development.[143]

[137] American Broadband Initiative (ABI), 2019, *Milestones Report,* https://www.ntia.doc.gov/files/ntia/publications/american_broadband_initiative_milestones_report.pdf

[138] ABI, 2019.

[139] ABI, 2019.

[140] Main Street America, “The Main Street Movement,” accessed March 17, 2020, https://www.mainstreet.org/mainstreetamerica/themovement

[141] National Trust, Main Street Program. https://www.mainstreet.org

[142] Federal Reserve System, Main Street Lending Program. https://www.federalreserve.gov/monetarypolicy/mainstreetlending.htm

[143] EPA Cool & Connected

Expected Benefits

Investing in town centers has the potential to increase concentrations of people and businesses in rural town centers. Redevelopment of historic storefronts can entice new businesses to open, attracting shoppers and other visitors. New residential development can attract people who value walkability and close access to jobs and services.

GHG Emissions. By increasing density of rural destinations, investments in town centers could decrease VMT, in turn reducing GHG emissions.[144] If more housing is concentrated in or near rural town centers, this will also reduce VMT. Members of a typical household might drive up to 32% fewer miles if their distance from a town center decreased by 50% (e.g., 10 miles to 5 miles).[145] A 32% decrease in VMT would save approximately 1.2 tons of CO_2e per vehicle per year.

Accessibility. Increasing density of destinations also improves accessibility. Non-drivers and vehicle-limited households in particular will benefit if goods and services become more accessible by walking or cycling. Town centers also provide a good environment for introducing public transit and shared mobility services.

Economic. Small town economies have taken a hard beating over the last two decades, but there is a widely recognized opportunity to now develop more vibrant and attractive communities. The opportunity is being driven by four factors:

- There is a desire of some millennials, and particularly high-tech workers, to live and work in rural areas that can offer attractive quality of life amenities. This has been enabled by technology enabling both remote working and entrepreneurial startups located in rural communities.[146] Business site location surveys corroborate the importance of quality of life factors among this demographic group.[147]
- The quality of life amenities that are important to this group include a clean environment, shops, recreation and walking, biking and transit options.[148] This is in addition to the broadband service required for high tech occupations. The lower rate of car ownership among millennials is also consistent with a desire for pedestrian and transit options in many areas.[149]
- Transit services are most viable and sustainable where they provide access linking people to work, shopping and entertainment/visitor destinations. This typically implies a focus on community business centers and destinations that provide a critical mass of transit demand.[150]

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[144] Mark R. Stevens, 2017, "Does Compact Development Make People Drive Less?" *Journal of the American Planning Association* 83 (1): 7-18.

[145] Stevens, 2017.

[146] Home Buyer and Seller Generational Report, National Association of Realtors, 2018. Findings are summarized in "Forget Big-City Living: More Millennials Are Transforming Small-Town America," Realtor.com, 3/14/2018, https://www.realtor.com/news/trends/millennials

[147] *Area Development* magazine's 2020 survey of corporate CEOs found skilled workforce and quality of life were rated among the top four site location factors. As noted in the article, *"tech-savvy millennials and GenZers — can be choosy about where they work so it's no surprise that the quality-of-life factor maintains a combined importance rating above 80."* https://www.areadevelopment.com/Corporate-Consultants-Survey-Results/Q1-2020/34th-annual-corporate-survey-16th-annual-consultants-survey.shtml

[148] "Transit and Livability: Results from the National Community Livability Survey," by Ranjit Godavarthy et al, Great Plains Transportation Institute, North Dakota State University for US DOT, 12/2018, https://www.ugpti.org/resources/reports/downloads/surlc18-008.pdf

[149] Mobility Mindset of Millennials in Small Urban and Rural Areas, by Natalie Villwock-Witte, Minnesota DOT, 2016. http://www.dot.state.mn.us/research/TS/2016/201635.pdf

[150] *Putting Transit to Work in Main Street America: How Smaller Cities and Rural Places Are Using Transit and Mobility Investments to Strengthen Their Economies and Communities,* Reconnecting America, 2012, http://reconnectingamerica.org/assets/PDFs/201205ruralfinal.pdf

- Economic developers are seeing vibrant towns with quality of life amenities as an attraction for high tech computer industries[151] as well as remote workers.[152] Businesses have been demonstrated to experience increased sales when they are clustered in commercial corridors that are accessible via walking or cycling.[153]

Public Health & Safety. Reduction in VMT through increased walking, cycling, and transit, and shorter driving distance will improve air quality and road safety. Increased walking and cycling are also associated with better health. Creating walkable communities can also reduce social isolation for non-drivers, including older adults and people with disabilities.

Table 27. Performance Impacts of Investing in Town Centers

GHG	Medium	Increasing density of destinations and housing near town centers and enabling more use of transit, walking, and cycling will reduce VMT and GHG emissions.
Accessibility	Medium	Improved diversity and increased quantity of businesses in town centers increases the access to destinations for rural populations that live in or near town centers, and especially improves accessibility for non-drivers in these communities.
Economic	High	Businesses sometimes experience increased sales when they are clustered in commercial corridors that are accessible via walking or cycling.[154]
Health & Safety	Medium	Lowering vehicle miles traveled can reduce the amount and associated societal costs of fatal and nonfatal crashes.

Policy Considerations

Table 28. Policy Considerations for Investing in Town Centers

Equity	Investing in town centers has the potential to make places more expensive to live. This could happen if demand for housing outpaces supply, which could be more likely in places that attract seasonal residents. At the same time, improved active mode accessibility and concentration of services in town centers allows non-drivers or those who would prefer not to drive – including older adults, youth, and people with disabilities – to reach jobs and services. Low-income people, who disproportionately spend on transportation, can benefit from transportation cost savings.
Resilience	Development of town centers where people access goods and services on foot or by bicycle can improve local resilience, as people can continue to access these services even if driving is not possible.
Rural Challenges	Lower density population can limit the potential for rural communities to switch to non-motorized modes.
Timeline	In theory, zoning changes can be made quickly, as can many sidewalk and bike facility improvements. Changes in development patterns may take longer to occur.

[151] *Putting Transit to Work in Main Street America: How Smaller Cities and Rural Places Are Using Transit and Mobility Investments to Strengthen Their Economies and Communities,* Reconnecting America, 2012, http://reconnectingamerica.org/assets/PDFs/201205ruralfinal.pdf

[152] *Putting Transit to Work in Main Street America: How Smaller Cities and Rural Places Are Using Transit and Mobility Investments to Strengthen Their Economies and Communities,* Reconnecting America, 2012, http://reconnectingamerica.org/assets/PDFs/201205ruralfinal.pdf

[153] Todd Litman, 2018, *Economic Value of Walkability,* https://www.vtpi.org/walkability.pdf

[154] Todd Litman, 2018, *Economic Value of Walkability,* https://www.vtpi.org/walkability.pdf

6. Multi-Criteria Analysis

Section 5 provided detailed analysis of the expected benefits of each investment option. Table 29 rates each of the proposed rural investments on the basis of how it addresses various benefit criteria. The benefit criteria include the applicable group, the nature of benefits for that group, and the time frame for realizing those benefits. The direct economic benefits for rural areas are those that expand jobs and income by one of three ways:

- Cost: it saves operating expenses, making local industries more competitive and giving residents more available funds for local discretionary spending
- Attraction: it enhances other factors affecting business site location decisions for various industries, and
- Access: it expands access for workers to find jobs, for businesses to attract workers and customers, and for households to access medical care and other services.

There are additional benefits that have a social benefit value, and these benefits also indirectly aid rural economies by making them more attractive places to live and work. They include safety and other, more general “quality of life” improvements.

For each type of rural investment shown in the table, the large check marks denote forms of benefits that are dominant factors motivating the use of these investment measures. There are also smaller gray check marks denoting other forms of benefit that are secondary or indirect benefits. The advantage of this format is that it emphasizes how the different types of rural investment affect different groups and create different types of benefits for those groups that can be realized over different time frames. This format emphasizes that these potential rural investments are not alternatives to be ranked and chosen, but rather, they are options that can all benefit make sense to be implemented over time in rural areas. Table 29 also shows the applicable markets for each solution and comments on the expected timeline for benefits to manifest. In some cases, such personal vehicle electrification, the technology exists and implementation can be initiated right away, but adoption is expected to be a slower process.

Table 29 Multi-Criteria Rating of Rural Benefits from Investment Options

Type of Rural Investment	Expected Impacts					Addresses Equity Needs	Time Frame
	GHG	Access	Economic		Health & Safety		
			Save Cost	Attract Business			
Personal vehicle technology	✓		✓		✓		Medium-term
Municipal fleet vehicle technology	✓		✓		✓	✓	Short-term
Freight Truck vehicle technology	✓		✓		✓		Medium to Long-term
Truck stop electrification	✓		✓		✓		Medium-term
Intermodal freight (rail, barge)	✓			✓	✓		Long-term
Local and regional transit	✓	✓	✓		✓	✓	Short-term
Long-distance bus & rail	✓	✓	✓		✓		Short-to-medium term
Rural broadband	✓	✓		✓		✓	Short-term
Small town centers	✓	✓		✓	✓	✓	Medium-term

There are significant complementarities and potential synergies among these various types of rural investment. For instance, the first four involve adoption of newer technologies affecting vehicle engines (electric motors) and operating systems (electronic controls) that provide cost and safety benefits. While they are applicable to different markets, they can all gain from adoption of common vehicle and charging station technologies. The next three involve investments to encourage and enable broader transportation mode options in rural areas. While they also apply to different markets, they all gain from wider choices that open new markets for businesses and people. The last two are not strictly transportation improvements, but rather, they are investments that complement and enhance transportation improvements by providing broader ways for people to access jobs and services. Altogether, these results provide a framework for policy decisions by showing how rural areas can benefit in different ways from implementation of various targeted investments.

7. Conclusions

In conclusion, the rural portions of TCI states have needs that are distinct from their urban counterparts. On average, the rural population is older, lower income, and has a higher share of people with disabilities. Rural households tend to drive more and are much less likely than urban dwellers to use public transit, due to its limited availability. The combination of these factors means that people in rural areas spend more of their incomes on transportation and are concerned that that many of the potential transportation investment options will not benefit them.

Given this context, transportation investments that improve access and make transportation more affordable in rural areas are critical. This report evaluates transportation investment options that can address rural needs in terms of not only GHG emissions, but also in terms of their impacts on accessibility, the economy, public health, and safety.

Because the rural areas that span the TCI states are not homogenous, this report provides information to enable policymakers to identify the solutions that best suit the needs of their communities. To that end, it also includes information on policy considerations, including how the solutions address equity and resilience, challenges to implementing them in rural areas, and expected timeline for implementation and impacts.

A1 Methodology

We used the USEPA's Motor Vehicle Emissions Simulator (MOVES)[155] model to analyze the emissions effects of the different policy scenarios by estimating tailpipe emissions rates for several NAAQS criteria pollutants and precursors, and used FHWA Highway Performance Management System (HPMS) data to estimate typical annual vehicle activity on rural roads in the proposed TCI region.[156] The specifics of those methodologies, including a full modeling run specification (runspec) are detailed below.

Emissions Inventories and Rates

We modeled master national emissions inventories in MOVES using a wide range of parameters, and post-processed emissions rates for analysis. Selected criteria pollutants include carbon monoxide (CO), nitrogen oxides (NOx), sulfur dioxide (SO2), volatile organic compounds (VOCs), coarse particulate matter (PM10), and fine particulate matter (PM2.5). We estimated emissions rates for carbon dioxide equivalent (CO2e) as our measure of GHG emissions, and separately estimated total energy consumption (TEC).

We estimated national emissions rates for each pollutant, precursor, and for energy consumption, resulting in rates by vehicle type, road type, activity type (running, starts, extended idling), and analysis year. In order to achieve localized estimates, we applied these national emissions rates to regional activity information from HPMS, as described in the next section.

We modeled national emissions inventories for all model years and fuel types available in MOVES. As a result, our post-processed emissions rates represent the national average emissions rate for a given pollutant or precursor. The results of analysis using these rates provide an order-of-magnitude estimate of emissions effects from given project types.

In the master MOVES runs, we estimated emissions rates for all available road types: urban restricted, urban unrestricted, rural restricted, and rural unrestricted. The "restriction" refers to whether the road is a restricted-access highway, and influences the modeled drive cycle characteristics, including acceleration trajectories and speed. To ensure a rural focus, our analysis used only emissions rates associated with rural road types, and allocated activity according to HPMS data.

MOVES includes assumptions of how the fleet will change over time, allowing modeling in different future evaluation years. Since vehicle electrification and other strategies will be implemented over time at an unknown rate of progress, we estimated emissions rates for three analysis out-years: 2020, 2030, and 2040. In our analysis, we multiplied annual activity estimates by the average of these three rates sets. As a result, our emissions benefits results indicate the expected typical value in a given year between 2020 and 2040. We believe this makes for a conservative estimate, as emissions control technologies are likely to improve over time, especially if TCI investments shift the regional vehicle fleet towards high-efficiency engines and alternative fuels.

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[155] We used the most recent available version of MOVES2014b (December 2018) The latest version of MOVES may be accessed: https://www.epa.gov/moves/latest-version-motor-vehicle-emission-simulator-moves

[156] Activity estimates come from HPMS Tables VM-2 and VM-4 (https://www.fhwa.dot.gov/policyinformation/hpms.cfm), as well as the Department of Energy's Alternative Fuels Data Center (AFDC) Table 10309 (https://afdc.energy.gov/data/10309).

Activity Estimates

Vehicle activity represents the quantity of a given emissions process, to which an emissions rate is applied to produce an emissions estimate. There are two dimensions to vehicle activity: emissions process and activity quantity:

$$E_i = \sum_{j \in J} A_{i,j} * ER_{i,j}$$

Where:

i is the emissions process or activity type
j is the vehicle type
J is the set of vehicle types
A is the amount of activity for the given process i and vehicle type j
ER is the emissions rate for the given process i and vehicle type j
E is the emissions quantity for process i

We estimated three activity types in MOVES, which consisted of at least one emissions process. These were combined into respective emissions rates for each type.

1) Running emissions, which includes running and crankcase running processes;
2) Starting emissions, which includes starting and crankcase starting processes;
3) Extended idling, which includes idling and crankcase idling processes.

We then estimated activity quantities for each MOVES vehicle type. We used HPMS Tables VM-2 and VM-4 to estimate the number of miles driven by each vehicle type and the proportion of miles driven on each road type in the combined TCI region; we supplemented this with the Department of Energy's AFDC Table 10309, which details average annual vehicle miles for different vehicle types not covered by HPMS. These transformed values were fed into scenarios for each policy proposal in the report.

Battery-Electric and Hybrid-Electric Vehicles

Our estimated emissions rates indicate tailpipe emissions only, and do not include upstream energy inputs and emissions. As a result, battery-electric vehicles (BEVs) are estimated here to have zero emissions.

While many types of hybrid-electric vehicles (HEVs) exist, including vehicles that can fully rely on battery power for extended activity, most of these vehicles include a conventional engine to recharge the battery once stored power is depleted. Therefore, in an effort to remain conservative and acknowledge rural drive cycles, we assume that HEV powertrain systems are simply more efficient conventional vehicles. To estimate HEV scenarios, we applied a 30% efficiency factor to the estimated emissions from conventional vehicles.[157] This is slightly lower than figures found in the scientific literature: those studies have primarily analyzed urban scenarios, which likely do not account for rural drive cycles.[158]

Non-Exhaust Particulate Matter

Vehicle activity emits particulate matter (PM) of various sizes and quantities, depending on a host of factors including fuel type, drive cycle, and certain aftermarket technologies. While exhaust

[157] This efficiency factor is based on the Department of Energy's AFDC estimates. https://afdc.energy.gov/fuels/electricity_benefits.html#savings

[158] Robb Barnitt, "In-Use Performance Comparison of Hybrid Electric, CNG, and Diesel Buses at New York City Transit" (National Renewable Energy Laboratory, June 2008); L Zhang, T Brown, and GS Samuelsen, "Fuel Reduction and Electricity Consumption Impact of Different Charging Scenarios for Plug-in Hybrid Electric Vehicles," *Journal of Power Sources* 196, no. 15 (August 2011): 4.

emissions from fuel combustion have been reduced throughout the fleet as a result of regulations requiring advanced filters and catalytic processes, non-exhaust PM emissions from brakewear and tirewear remain a major concern.[159] By some estimates, non-exhaust emissions account for 90% of PM_{10} and 85% of $PM_{2.5}$.[160]

BEVs are generally heavier than their conventional counterparts, as a result of having massive on-board electrical systems. By convention, emissions analysis has therefore frequently assumed that BEVs emit *more* non-exhaust PM than conventional vehicles, even as exhaust emissions reduce to zero, because of greater forces acting on tires and brakes. However, recent research suggests that the co-incidence of regenerative braking systems with BEVs means that non-exhaust PM emissions are roughly the same as conventional vehicles: the increases in tirewear from greater weight are washed out by net decreases in brakewear from regenerative braking.[161]

Therefore, our analysis assumes no change in brakewear or tirewear PM in any vehicle electrification scenarios, i.e. fleet conversion to BEVs. We assume that non-exhaust PM emissions benefits from HEV conversions are included in the 30% efficiency improvement discussed earlier.

Social Valuation Parameters

We used the following factors value the social cost of emissions.

Pollutant	Social Cost (2018$)	Source
NOx	$8,600	US DOT BCA Guidance, Jan 2020, Table A-6: Damage Costs for Pollutant Emissions, $2018 dollars per US short ton.
SOx	$50,100	
VOC	$2,100	
$PM_{2.5}$	$387,300	
CO2e	$78	World Bank: Shadow Price of Carbon

For safety analysis, we used KABCO factors from the US DOT BCA Guidance, Jan 2020.

KABCO Level	Monetized Value per Crash ($2020)
Fatalities	$9,991,332
Injury - Incapacitating	$477,815
Injury – Non-Incapacitating	$130,095
Possible Injury	$66,505
Property Damage Only	$3,330

Public Transit Analysis

The estimated GHG reduction and criteria pollutant impacts from investment in public transit is based on the above emission rates and estimates of cost per trip, occupancy and trip length data including:

[159] Richard Lofthouse, "Pollution from Tyer Wear 1,000 Times Worse than Exhaust Emissions," *Emergy Analytics*, n.d., 16 April 2020.

[160] Victor Timmers and Peter Achten, "Non-Exhaust PM Emissions from Electric Vehicles," *Atmospheric Environment*, no. 134 (March 2016): 10–17.

[161] Timmers and Achten.

- The operating costs per rural transit trip in the TCI region (average $10.06)[162]
- The expected reduction in single-occupancy light-duty vehicle trips (approximately 0.55 per new transit trip).[163]
- The average trip length (14.2 miles)[164]

[162] National Transit Database, 2018. Excludes inter-city services, limited to rural transit agencies that report to the National Transit Database

[163] Based on survey responses to alternate modes of public transit riders compiled in APTA Who Rides Public Transportation (2017)

[164] ACS 5-year estimates 2012-2017, commute to work in rural TCI region