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Electric, Hybrid and High Fuel Efficiency Vehicles: Cost-Effective and Equitable GHG Emission Reductions in Maine

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Abstract

Maine's transportation sector accounts for 54% of Maine's CO2 emissions, with almost all of this coming from gasoline and diesel (MDEP 2020). On a per-capita basis, Maine's transportation sector is about average for the nation (rank 24 out of 50). Reducing transportation-related petroleum demand and emissions will benefit Maine's economy. This can be achieved by increasing vehicle efficiency, switching to alternative fuels (e.g., electricity, biofuels) that have lower emissions per mile, and by reducing the demand for motorized transportation. These actions can and should be done while meeting social equity goals that account for regional, income and racial inequalities. The GHG benefits of electric vehicles (EVs) are particularly strong in states such as Maine that have electrical grids relying on renewable energy sources and natural gas. However, given the low current sales rate of new EVs, less than 2% in Maine, EV-focused programs do not affect the overwhelming majority of current new vehicle purchases. We provide some estimates of possible fuel and GHG savings from a used high mile-per-gallon (MPG) vehicle incentive program for Maine. These are based on common Maine vehicles and represent savings if drivers participate in the program. The GHG emission reductions realized will depend on the specifics of the program implementation and the linkage of such a program with a scrappage program to remove the least efficient vehicles from Maine's roads.

Acknowledgements and Disclaimers

This study would not have been possible without the strong cooperation of the Maine Department of Transportation and the Maine Department of Environmental Protection. We would like to specifically recognize the following individuals: Joyce Taylor, Taylor LaBrecque, Dale Peabody, Dawn Bickford, Denise Cormier, and Lynne Cayting. The views and opinions expressed in this report are solely those of the Margaret Chase Smith Policy Center and the individual authors. They do not represent those of Maine Department of Transportation, Maine Department of Environmental Protection or any other individual or organization that has provided information or assistance.

Executive Summary

Maine's transportation sector accounts for 54% of Maine's CO2 emissions, with almost all of this coming from gasoline and diesel (MDEP 2020). On a per-capita basis, Maine's transportation sector is about average for the nation (rank 24 out of 50). Reducing transportation-related petroleum demand and emissions will benefit Maine's economy. This can be achieved by increasing vehicle efficiency, switching to alternative fuels (e.g., electricity, biofuels) that have lower emissions per mile, and by reducing the demand for motorized transportation.

This report presents the current inventory of Maine's light-duty vehicle fleet (sedans, pickup-trucks, SUVs, minivans) and estimates the GHG emission savings from a used vehicle rebate program. We also offer some suggestions to enhance social equity by providing subsidized financing for qualified buyers.

Maine's Light-Duty Vehicle Fleet

Maine's light-duty fleet includes approximately 1,121,400 registered vehicles (July 2020). Maine's on-road vehicle fleet has an average age of 10 years, compared to the national average age of 11.8.

- The average efficiency of Maine's passenger vehicle fleet is 22.4 miles per gallon (MPG), almost exactly the national average.
- Given the on-going shift towards SUVs and away from passenger cars, the overall fuel economy on Maine's roads is unchanged for the last 5 years.
- With all model years combined, Maine's fleet is comprised of 41% SUVs, 29% sedans, 21% pickup trucks, 5% Hatchbacks, 2% minivans, and 1% other.
- On Maine's roads, 38% of vehicles are rated less than 20 MPG, whereas only 8.4% are rated 35 MPG or more.
- SUVs represent the largest share of CO_2 emissions on Maine's roads because they represent the largest share of vehicles and have below average fuel efficiency.
- The number of EVs still make up a small proportion (< 2%) of light-duty vehicles in Maine. In addition to dedicated electric vehicles there are several models of gasoline-electric hybrid and high efficiency gasoline vehicles with fuel efficiency of 40 MPG or more. Various models of the Toyota Prius family are by far the largest group; the Ford Fusion hybrids and Toyota RAV 4 Hybrid are also popular.
- The existing distribution of EVs shows a positive correlation between per capita income and EV registrations.
- About half of Maine residents live in predominantly rural areas where there are higher rates of vehicle ownership, and the vehicles are older and less efficient that in urban areas.

Fuel and Emissions Savings Estimates for Used High MPG Vehicle Program

We provide estimates of possible fuel and GHG savings from a used high MPG vehicle incentive program for Maine. We compare 5 popular vehicle models of different size classes with newer, more fuel efficient, but comparable vehicles. The highly fuel efficient conventional and hybrid used vehicles are all model years 2017, whereas the older and less fuel-efficient, but similar,

vehicles are model years 2011. Fuel savings calculations include both the cost of gasoline and electricity, and assume that vehicles are driven 12,000 miles per year and gasoline is at $2.80/gallon. We estimate that the 5 replacement pairs save between 12.6 to 34.5 $MTCO_2$ over 10 years. The average reduction for all 5 pairs, is 27.1 MTCO2 over 10 years. The cost to the state of reducing a metric ton of CO_2, calculated by dividing a $2,000 rebate by the CO_2 savings, ranges from $58-158 / $MTCO_2$. On average, the 27.1 $MTCO_2$ savings cost $94/$MTCO_2$, equivalent to 4.3¢ / $lbsCO_2$. The GHG emission reductions realized will depend on the specifics of the program implementation, the willingness of consumers to use the program, and the linkage of such a program with a scrappage program to remove the least efficient vehicles from Maine's roads.

Programs Targeting Low-Income and Disadvantaged Households

Efficiency Maine currently offers enhanced rebates for new and used EVs for qualified low income households. We estimate that approximately 30% of Maine households are eligible for these enhanced rebates based on Efficiency Maine's income guidelines (based on LIHEAP eligibility). If Maine were to enact the same income eligibility requirements as the Vermont Mileage Smart program (80% of median income), an additional 11% of Maine households would be eligible for the increased rebate. Loosening the eligibility would increase the program's costs.

Because middle- and lower-income individuals may not have access to low-cost conventional automobile loans, we recommend that Maine consider setting up a publicly funded loan loss reserve (LLR) program. LLRs provide loan loss coverage to financing partners such as local and regional banks and credit unions. These programs are a form of credit enhancement that can offer below-market-rates to increase the affordability of higher fuel economy used conventional and electric vehicles to identified groups to enhance social equity.

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Introduction

Maine's transportation sector accounts for 54% of Maine's CO2 emissions, with almost all of this coming from gasoline and diesel (MDEP 2020). On a per-capita basis, Maine's transportation sector is about average for the nation (rank 24 out of 50).1 Reducing transportation-related petroleum demand and emissions will benefit Maine's economy. This can be achieved by increasing vehicle efficiency, switching to alternative fuels (e.g., electricity, biofuels) that have lower emissions per mile, and by reducing the demand for motorized transportation. The can and should be done while meeting social equity goals that account for regional, income and racial inequalities.

The GHG benefits to electric vehicles (EVs) are particularly strong in states such as Maine that have electrical grids relying on renewable energy sources and natural gas. However, given the low current sales rate of new EVs, less than 2% in Maine, EV-focused programs do not affect the overwhelming majority of current new vehicle purchases. This will be true for years even given the large increase in EV sales predicted by the US Department of Energy (US EIA 2020). Moreover, evidence from California, the US state with the highest adoption rate of EVs, finds that new EV car buyers are wealthier and tend to have higher levels of education (Hardman et al. 2018). Less is known about EV demand by low- and middle-income households and the policies that are necessary to expand EV adoption (Muehlegger and Rapson 2018). Pierce et al. (Pierce et al. 2019) found evidence of low- and moderate-income households' greater dependence on used vehicles, lower reliance on traditional financing, and concerted disinterest in alternative travel modes. Stated preference surveys suggest that further investment in new and used clean vehicle purchase incentives for low- and moderate-income households would be cost-effective.

We provide some estimates of possible fuel and GHG savings from a used high MPG vehicle incentive program for Maine. These are based on common Maine vehicles and represent savings if drivers participate in the program. The GHG emission reductions realized will depend on the specifics of the program implementation and the linkage of such a program with a scrappage program to remove the least efficient vehicles from Maine's roads.

Importance of raising the fuel economy of low MPG vehicles

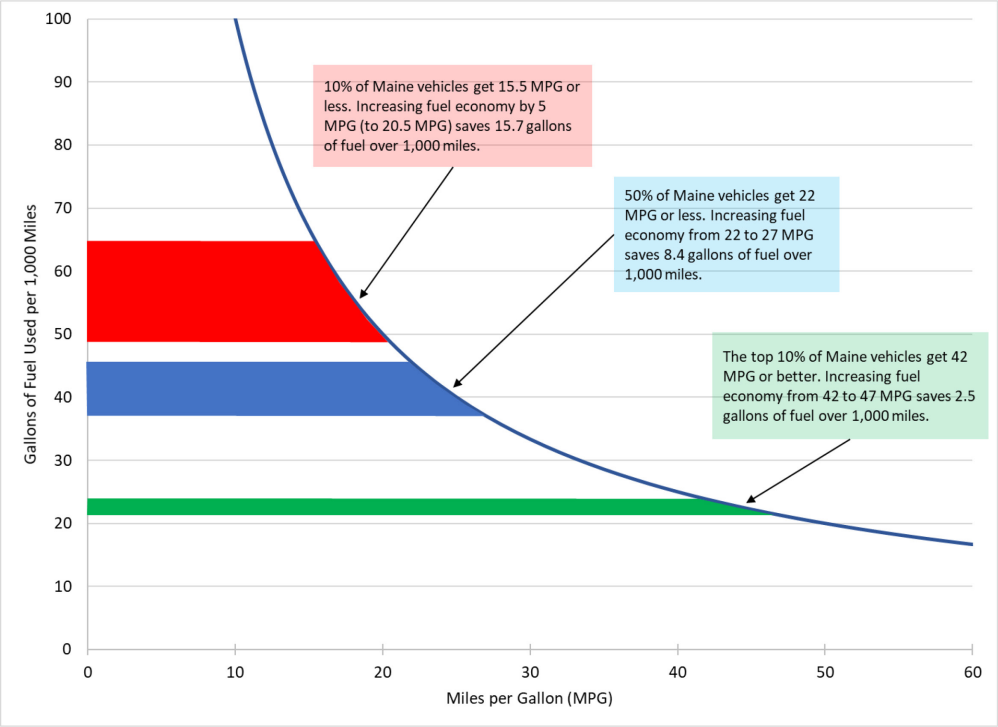
Reducing fuel costs and GHG emissions is not just about new, highly efficient battery electric vehicles (BEVs), plug-in hybrid electric and gasoline vehicles (PHEVs), hybrid vehicles (HEVs) and high fuel efficiency gasoline and diesel vehicles. It is also about raising the fuel economy of the whole vehicle fleet.

Fuel economy is measured in terms of miles-per-gallon (MPG) rather than gallons used over a given distance. This means the relationship of MPG and fuel use is not linear. As seen in Figure 1, an increase in fuel economy by 5 MPG does not add up to the same amount of fuel savings in vehicles with two different fuel efficiencies. The fuel, money and GHG emission savings are

[1] Authors' calculation based on US EIA and Census data (US Census Bureau, Population Division 2019; US Energy Information Administration (EIA) 2018).

significantly greater when replacing a low-MPG car or truck with a highly efficient vehicle, new or used, driven the same amount.

Figure 1: Comparison of fuel usage vs fuel economy: 2019 Maine light-& medium-duty vehicles

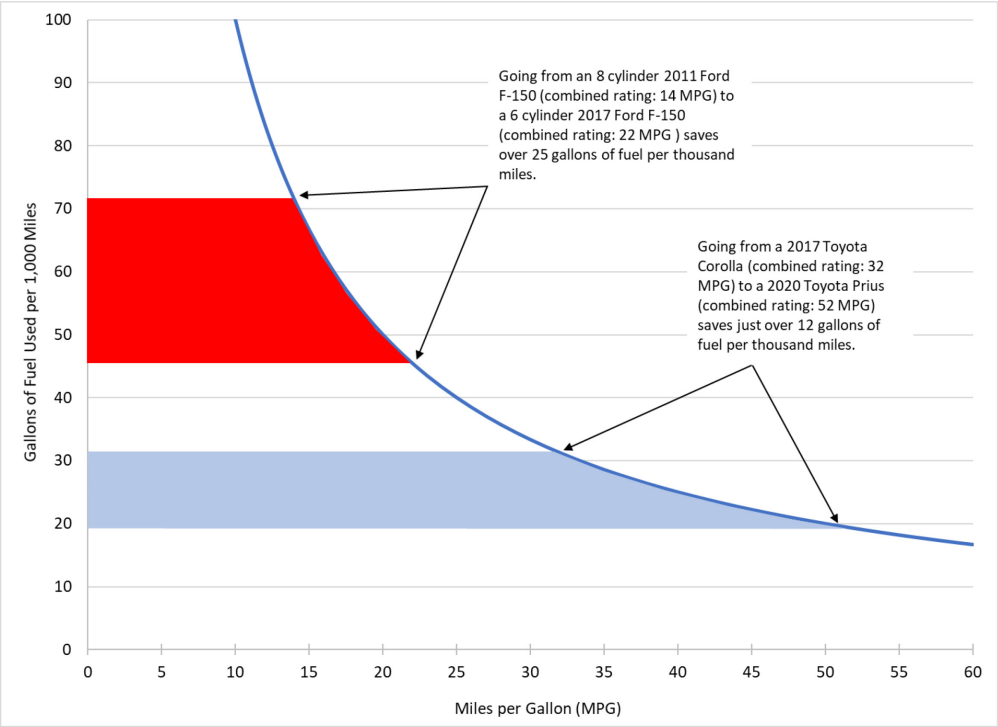


Data from Maine's light- and medium- duty vehicle fleet (<10,000 lbs.) shows that 10% of Maine's vehicles get 15.5 MPG or less. Increasing the fuel economy from 15.5 MPG to 20.5 MPG saves 15.7 gallons of fuel over 1,000 miles. Alternatively, the most efficient vehicles in Maine get at least 42 MPG. Increasing the fuel economy to 47 MPG saves just 2.5 gallons of fuel over 1,000 miles. For the least efficient sector, even a modest gain in fuel economy (5 MPG) would significantly reduce the fuel usage and GHG emissions over time.

As seen in Figure 2 upgrading from a 2011 Ford F-150 to a 2017 Ford F-150, an 8 MPG increase in fuel efficiency, saves 25.97 gallons of gasoline per 1,000 miles traveled. In comparison, upgrading from a 2017 Toyota Corolla to a 2020 Toyota Prius, a 20 MPG increase in fuel efficiency, saves 12.01 gallons of gasoline per 1,000 miles.[2]

[2] Figure inspired by Davis and Boundy, 2020.

Figure 2: Comparison of fuel usage vs fuel economy for select vehicle models.



Used Highly Efficient Vehicles

Nationwide, the volume of used car sales represents two-thirds (66%) of total sales including new cars and leases (BTS, US DOT 2019). As is recognized in Maine's Climate Change Transportation Working Group, as well as other national low-carbon transportation emission plans, reaching zero or very low GHG emissions in the transportation section requires the shift towards electric propulsion from battery electric or hydrogen fuel cell vehicles (Sperling et al. 2020). In the immediate future, accelerating fleet turnover using incentives, coupled with a vehicle scrappage program, to use more fuel-efficient vehicles can reduce GHG emissions and provide fuel savings to drivers today.

An incentive program including used highly efficient conventional vehicles as well as used EVs (dedicated), plug-in (PHEV) and non-plug-in hybrid vehicles (HEVs) would increase the administrative complexity of an incentive system. At the same time, such a system would significantly expand the choice of vehicles. The system would need to be designed to avoid giving credit to transfers within a family or friendship group motivated purely by the incentive rather than the intent of reducing fuel costs and emissions. One approach, that does not require a point-of-sale rebate is to apply a sliding registration fee based on the vehicle's MPG (Cambridge Systematics, Inc. 2019). A more complex fee system could account for the income of vehicle purchasers, to avoid becoming a regressive tax.

The Vermont Legislature commissioned a report to investigate the benefits of a vehicle incentive program to promote highly efficient vehicles using a feebate (Cambridge Systematics,

Inc. 2019).[3] A feebate is a market-based policy approach to lowering transportation fuel consumption and GHG emissions. A fee is assessed on the purchase of vehicles that emit more GHGs and use more fuel and a corresponding rebate is provided to purchasers of low fuel using and low GHG vehicles. This feebate was designed to be self-funding and revenue neutral, so that the cost of incentivizing cleaner vehicles is offset by the corresponding fee portion of the policy. This report looked at five feebate options in terms of effectiveness, administrative complexity, and equity. Alternatives 1 – 4 included new vehicles purchases only, while Alternative 5 included new, *used*, and leased vehicles into the feebate structure. A summary table of the results can be found below in Table 1, which highlights the potential benefits of Alternative 5 in terms of emission reductions and equity.

Table 1: Summary evaluation of sample feebate alternatives (Cambridge Systematics 2019)

Policy Alternative	Effectiveness of Achieving Program Goals				Description
	Reducing GHGs	Increasing EVs	Manageable Administrative Cost/Effort	Fair and Equitable	
Alt. 1: All-Vehicle Feebate	3	1	2	2	Fee or rebate on all new vehicle purchases based on fuel efficiency.
Alt. 2: Categories of Vehicles Feebate	2	1	2	3	Feebate based on vehicle category (e.g. cars versus light-duty trucks)
Alt. 3: EV Rebate Paired with Other Short-Term Revenue	1	3	3	0	Expansion of current EV rebate system to include all EVs.
Alt. 4: EV-Focused Feebate	2	3	2	2	Feebate adjusted over time. As the market share of EVs increases, the ICE fee increases and the EV rebate decreases.
Alt. 5: Wider Net Leased and Used Vehicles	3	1	1	0/3	Includes new, used, and leased vehicles into feebate system.

Note: Effectiveness was evaluated on a 0-3 scale (0 - does not support criterion, 1 - somewhat supports criterion, 2 - supports criterion, 3 - strongly supports criterion).[4]

Choosing which vehicles to promote requires understanding the current vehicle fleet and how it is used as well as the characteristics of new vehicles coming onto the market. One approach would be to follow the lead of Japan's "Top Runner" program for automobiles which started in 1999. The top runner program for passenger vehicles identifies the most fuel-efficient automobile in each weight class and designates it the "top runner." Standards for all passenger

[3] In June 2019, the Vermont General Assembly enacted Act 59 relating to the Transportation Program and miscellaneous changes to laws related to transportation. In Section 46, the Legislature directed the Agency of Transportation to complete a study concerning whether Vermont should adopt a time-of-acquisition vehicle feebate program to act as a self-funding incentive program.

[4] Equity concerns from alternative 5 (wider lease and used vehicles) stem from the structure of the feebate system that might charge older, less fuel efficient vehicles a higher registration fee and use the revenues to subsidize high fuel efficient, new vehicles including EVs. The program would need to be designed to take this into account to avoid this unintended outcome. This could be done by taking vehicle age into account.

vehicles are then set, taking into consideration the "top runner" and the potential for technological innovation. By 2005, as a result of this program, the fuel efficiency of passenger vehicles had increased by 22.8% (Agency for Natural Resources and Energy 2010). This approach may be worth considering for Maine as a way to choose which highly efficient used vehicles should be eligible to participate in an incentive program.

One concern with subsidies to used vehicles is that it might cause in-state and out-of-state transfers within the market of existing used vehicles, rather than incentivizing the purchase of new high fuel-efficient vehicles. Yet, to the extent that the market price for used high fuel-efficient vehicles raises the resale value of new high fuel-efficient vehicles, this should reassure new vehicle purchasers that there is a strong resale value for their purchase of a highly efficient vehicle. Moreover, this provides purchasers of used high fuel-efficient vehicles cost savings today. Care must be taken, however, to couple a used vehicle incentive program with a scrappage program to get the highest GHG emitting vehicles off the road.

Maine's On-Road Vehicle Fleet

The fuel economy on Maine's on-road vehicles is the sales-weight fuel economy of individual makes and models. While all vehicle classes (described below) are becoming more efficient over time, primarily due to federal fuel efficiency standards (CAFE), the mix of vehicles is changing. Thus, the overall fuel economy on Maine's roads is unchanged for the last 5 years. This does not consider how far each vehicle is driven since we do not have good way to estimate vehicle miles traveled for each vehicle.

Methodology

Data on Maine's light-duty vehicles comes from Maine's Department of Environmental Protection (DEP), who have recently decoded the vehicle identification number (VIN) registration data for all vehicles in Maine, as of July 2020. We matched vehicle registration data (at a rate of 95%) with the fuel efficiency database from the U.S. Department of Energy (DOE) to examine the fuel efficiency of Maine's vehicle fleet.

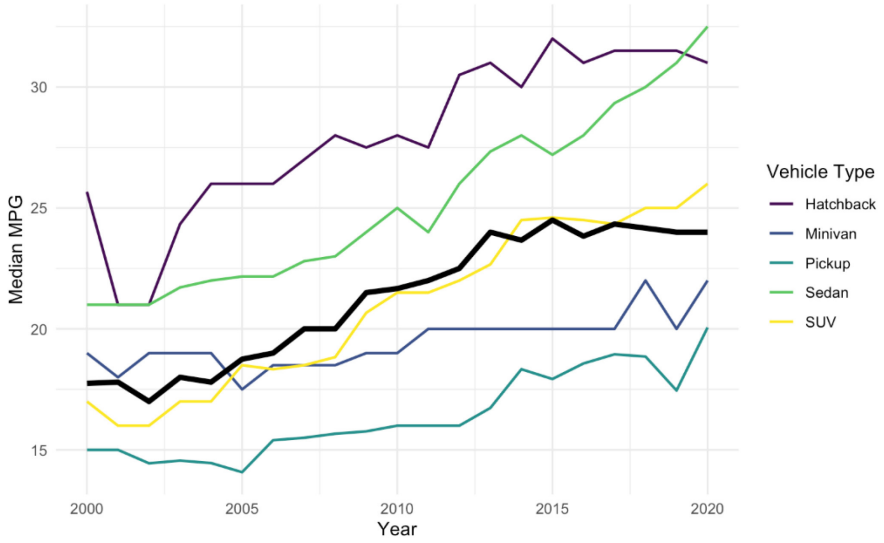
The matching process compares vehicle records from both databases based on filters to exclude incomplete or irrelevant registration entries. The six variables used to match the VIN registration data with the EPA MPG database are: make, model, model year, transmission type, trim, and EV type. We separately consider dedicated battery electric vehicles (BEV) and plug-in electric and gasoline hybrid vehicles (PHEVs). The transmission field in the VIN database was over 80% blank, but it is important for MPG determination, since the manual version of the same model is typically higher than the automatic version. We assigned blank transmission codes to automatic transmissions (less than 5% of new vehicles in the US have manual transmissions.) We excluded registration entries in the VIN database that included heavy-duty trucks of class 3-8, as well as motorhome chassis and trailer trucks. Vehicles with missing 'model' names were also excluded. Finally, we removed duplicate VINs, off-road vehicles, as well as vehicles from makes with fewer than 150 registered vehicles, mostly luxury, small or international makes, such as Ferrari, Peugeot or Daewoo.

Fuel Efficiency by Age and Class

The composition of Maine's light-duty fleet includes approximately 1,121,400 registered vehicles. Maine's on-road vehicle fleet has an average age of 10 years, compared to the national average age of 11.8 in 2019 (Bureau of Transportation Statistics 2020a). The average efficiency of Maine's passenger vehicle fleet is 22.4 miles per gallon (MPG), almost exactly the national average of 22.4 MPG in 2019 (Bureau of Transportation Statistics 2020b).

The fuel economy on Maine's roads by vehicle model year and class is shown in Figure 3 (July 2020). We see that the fuel economy of each vehicle class is increasing over time, though the rates of increase vary significantly by vehicle type. These improvements are largely the result of increasing federal fuel efficiency standards (CAFE). Counteracting this increase in fuel economy is the ongoing shift in consumer preference towards SUVs and light-duty trucks that generally have a lower fuel economy than sedans. The overall fuel economy on Maine's roads, shown by the heavy black line, is unchanged for the last 5 years, despite an increase in fuel efficiency in all vehicle classes over the same period.

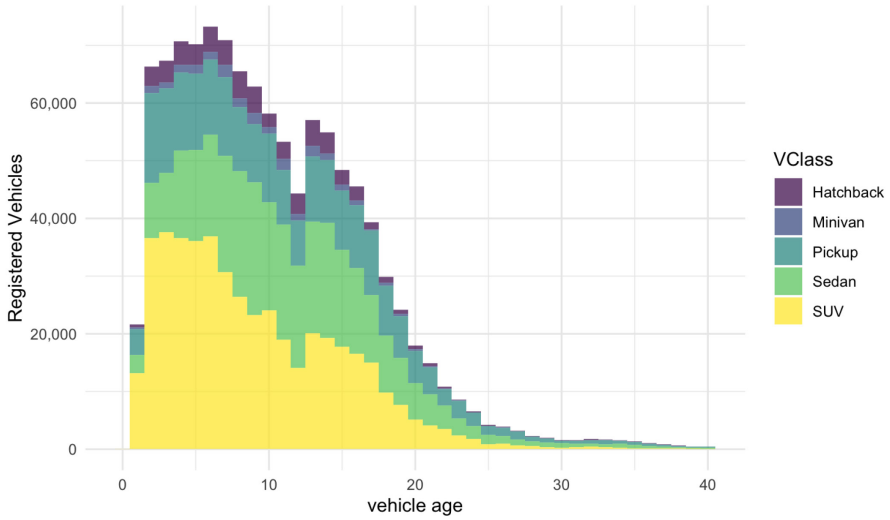
Figure 3: Fuel efficiency of Maine's vehicle fleet by class and age (July 2020)



Since vehicle types (e.g., sedan, SUV) have significantly different average fuel economies, the composition of the vehicle fleet matters for the overall fuel efficiency of Maine's on-road fleet. Accelerating the turn-over of the fleet should improve the overall fuel economy with the important caveat that increasing the proportion of vehicles that are pickup trucks and SUVs, at the expense of sedans and other high fuel efficiency vehicle classes, will reduce those improvements.

Maine's on-road light-duty vehicles includes a large proportion of pickup trucks and SUVs (62%), which generally have lower levels of fuel economy than sedans or hatchbacks. Figure 4 shows the distribution of vehicle types by model year. With all model years combined, Maine's fleet is comprised of 41% SUVs, 29% sedans, 21% pickup trucks, 5% Hatchbacks, 2% minivans, and 1% other. The proportion of SUVs relative to sedans has grown significantly over the last decade.

Figure 4: Age distribution of Maine's vehicle fleet (July 2020)



In Figure 5, we display Maine's on-road LDVs broken into fuel economy bins. This shows that 38% of vehicles are rated less than 20 MPG, whereas only 8.4% are rated 30 MPG or more.

Figure 5: Histogram fuel efficiency Maine vehicles

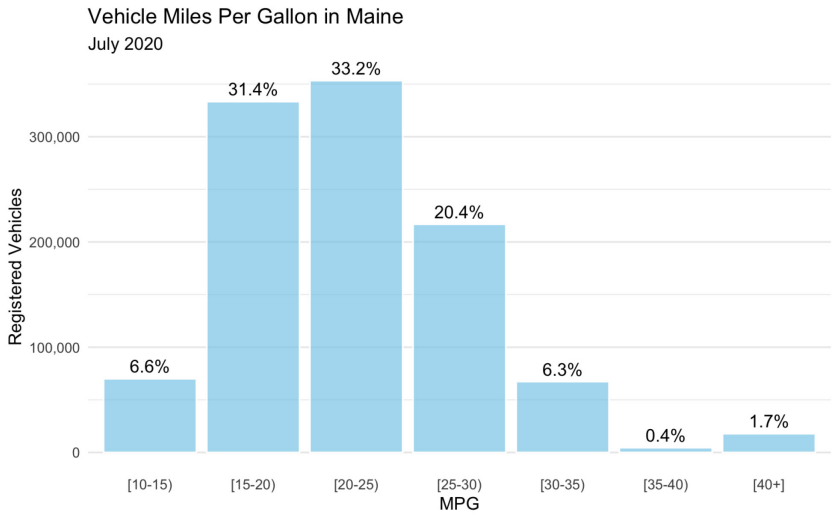


Figure 6 shows the distribution of vehicle type by fuel efficiency. As is readily seen, the lower fuel economy vehicles are pick-up trucks and SUVs.

Figure 6: Vehicle type and fuel efficiency of Maine LDV fleet (July 2020)

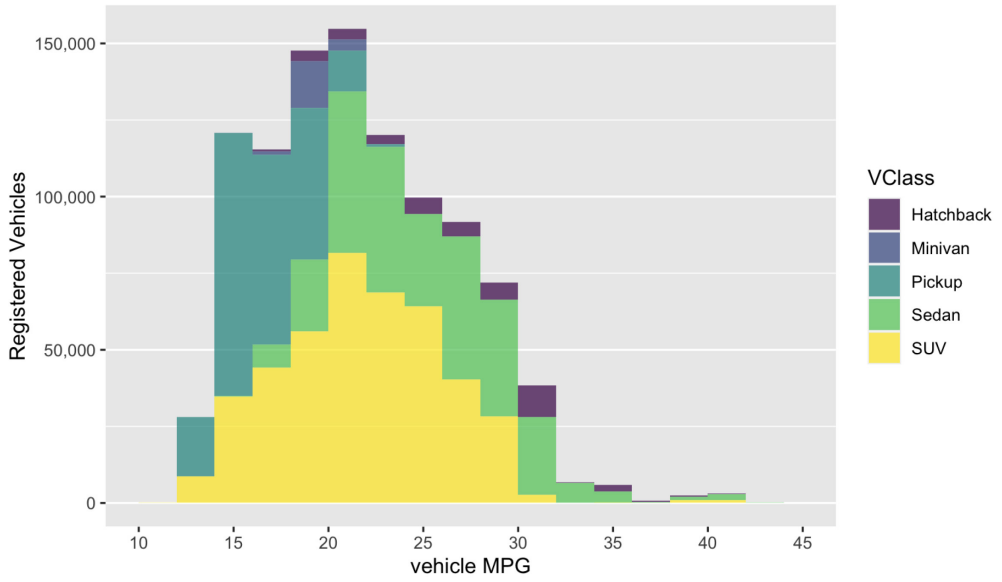
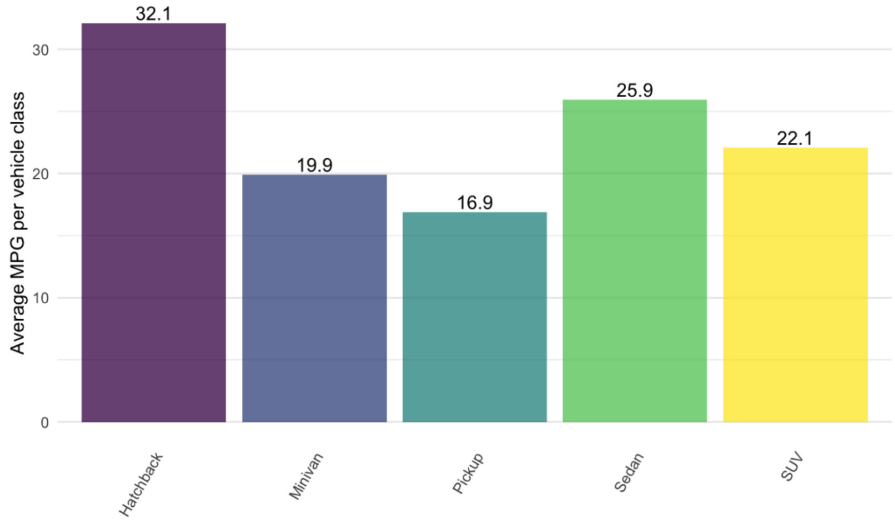


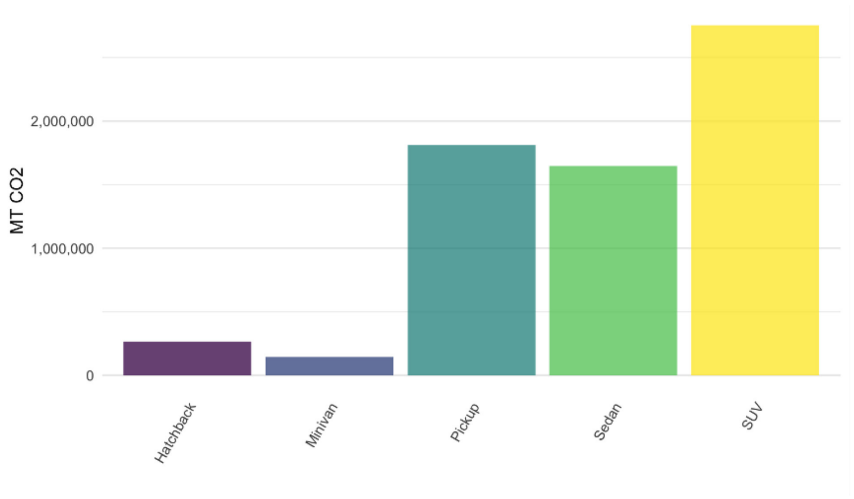
Figure 7 shows the average fuel economy of all vehicles on Maine's roads by vehicle type (average for all model years).

Figure 7: Average MPG by vehicle type, all model years in Maine's LDV fleet (July 2020)



Total annual CO_2 emissions by vehicle class are shown in Figure 8. Emissions are calculated based on the amount of fuel required for each vehicle to travel 12,000 vehicle miles per year. SUVs represent the largest share of CO_2 emissions on Maine's roads because they represent the largest share of vehicles and have below average fuel efficiency (22.1 MPG) compared to sedans and hatchbacks (25.9 and 32.1 respectively).

Figure 8: Total annual MT CO_2 emissions by vehicle type



Popular models

The Chevy Silverado is the most popular light-duty vehicle model in Maine (registered, on-road vehicles). Pickup trucks and SUV models are 8 of 10 most popular models in Maine, see Figure 9, which, usually, except for uncommon exceptions, have lower fuel economy than sedans.

The fuel efficiency of each of these models varies and is shown in Figure 10.

Figure 9: Top 20 vehicles models in Maine's light-duty vehicle fleet

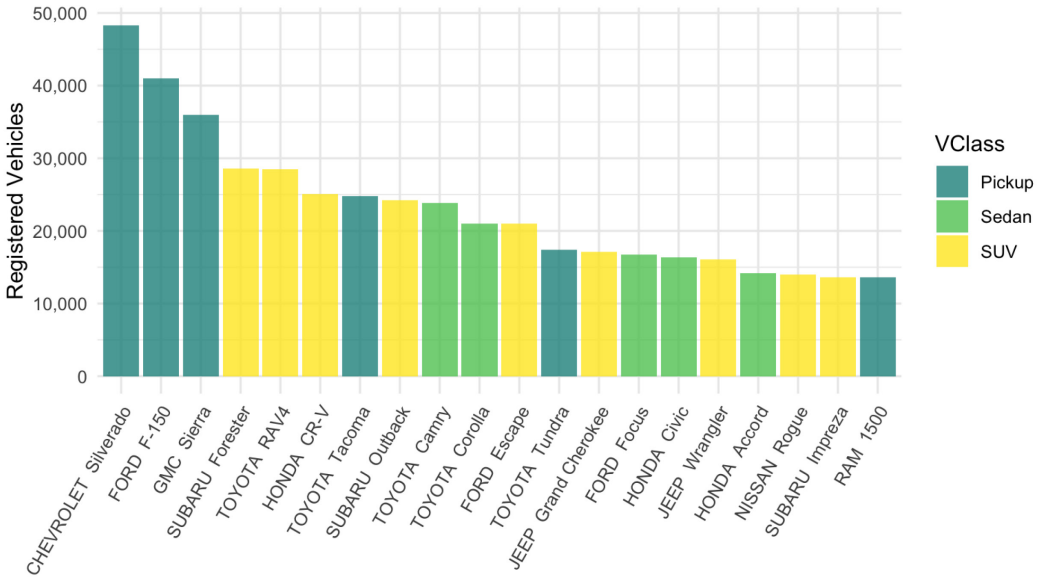
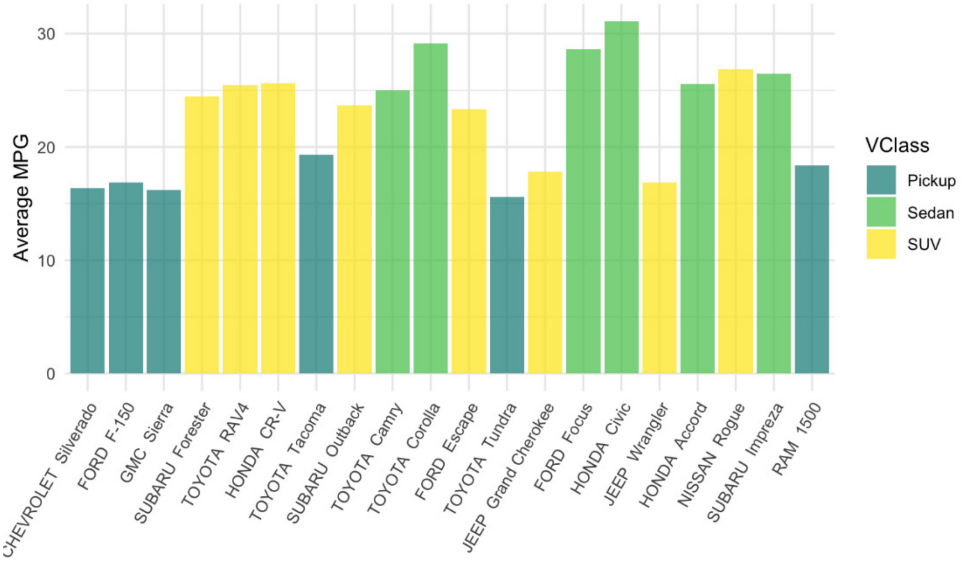


Figure 10: Average fuel efficiency of popular models in Maine



Currently, there are very few, if any, commercially available EV or PHEV pickup trucks and SUVs. The forthcoming availability of electric SUVs and pickup trucks has the potential to make a substantial impact on reducing Maine's transportation GHGs. Since on-road fuel economy of the vehicle fleet is increasing primarily due to national fuel economy standards, increasing the share of new and used high fuel efficiency vehicles on Maine's roads will save fuel costs and GHG emission reductions.

Hybrid and Electric Vehicles in Maine

In Maine, like the nation, the number and proportion of PHEVs and EVs has been increasing. Shown in Table 2 are data showing the increase in these vehicles since 2015. The number of EVs still make up a small proportion of light-duty vehicles in Maine. In addition to PHEVs and BEVs, there are several models of gasoline hybrid and high efficiency ICE vehicles with rated MPGs of 40 or more. Toyota Prius models are by far the largest group, and the Ford Fusion hybrid are also popular, see Figure 11 and Figure 12.

Table 2: Maine electric vehicle registration trends

Vehicle Type	2015	2016	2017	2018	2019
BEV	213	265	380	553	966
PHEV	651	827	1079	1473	2010

Figure 11: Most popular BEV and PHEV models in Maine

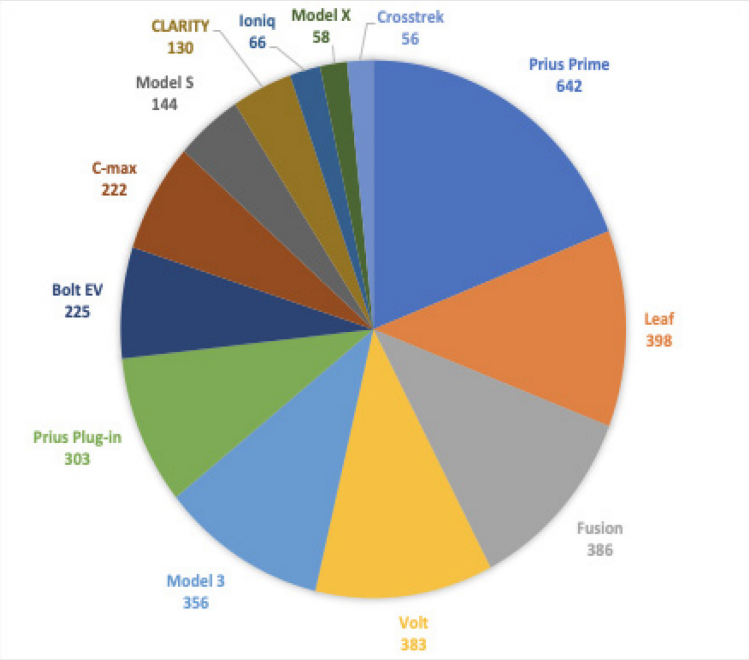
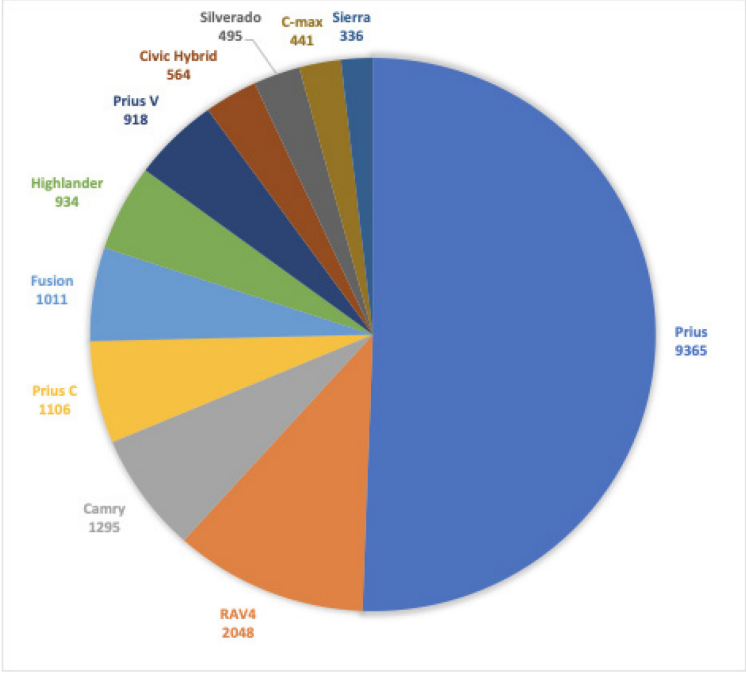


Figure 12: Most popular hybrid models in Maine



Spatial Pattern of Vehicle Ownership and Fuel Economy

The total population of each county in Maine, from the 2017 American Community Survey, is show in Figure 14. In order to understand difference in vehicle ownership across urban and rural areas, we've used the US census definition of rural and urban residents[5] to develop a classification of municipalities (mapped in Figure 13) as follows:

- **Cities** are townships with more than 10,000 urban residents;
- **Towns** are townships with between 2,500 to 10,000 urban residents;
- **Rural Areas** are townships with fewer than 2,500 urban residents.

Figure 13: Township Population, 2017

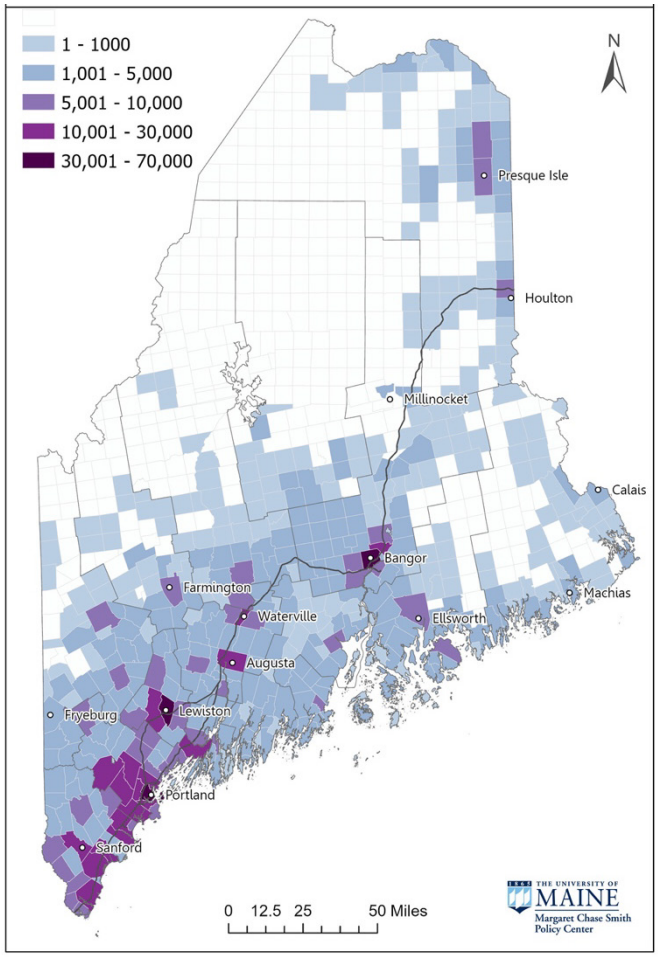
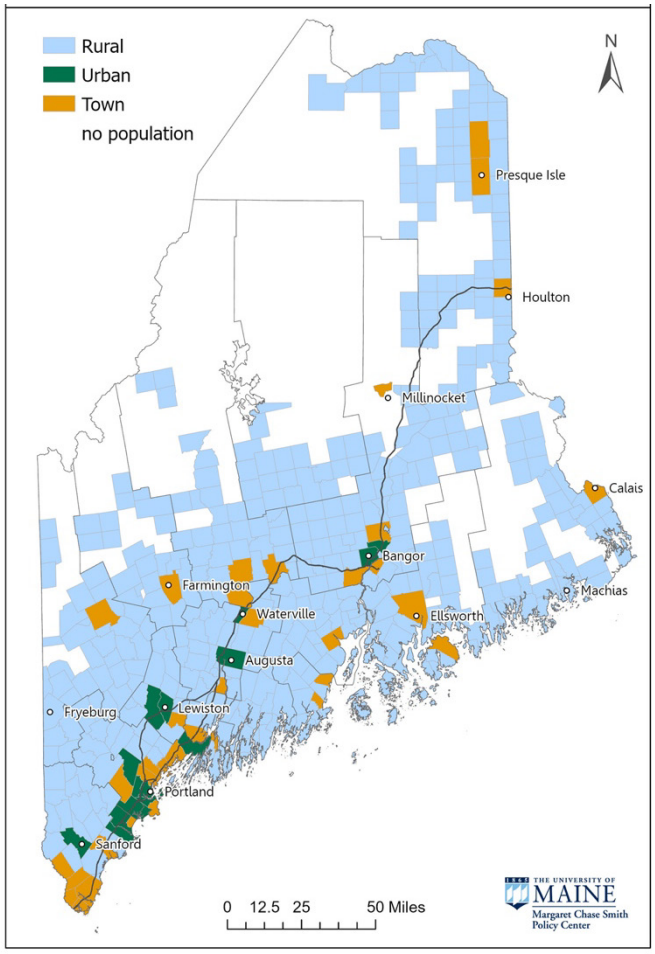


Figure 14: Urban and Rural Townships



About half of Maine residents live in predominantly rural areas where there are higher rates of vehicle ownership, and the vehicles are older and less efficient that in urban areas – see Table 3. Vehicles in rural areas are on average 1.6 years older, and less fuel efficient by 2 mpg.

[5] https://www.census.gov/programs-surveys/geography/guidance/geo-areas/urban-rural.html

Table 3: Vehicle Ownership Rates Per Capita: Rural, Town, Urban

Class	Population	Registered Vehicles	Vehicle per Capita	Percent of Maine's Population	Percent of Maine's Vehicles	Average Vehicle Age	Average Fuel Economy (MPG)
Rural	644,295	645,513	1.00	49%	54%	11.1	21.4
Town	284,504	252,618	0.89	21%	21%	9.9	22.8
Urban	366,940	294,412	0.80	28%	25%	9.5	23.5

Maine registration statistics on vehicles-per-capita and MPG can be seen aggregated to the municipal level in Figure 15 and Figure 16. Both figures show significant spatial heterogeneity. Particularly striking is the MPG by municipality in Figure 16 that shows that rural areas farthest from the I-95 corridor generally have lower fuel economy vehicles, but also a higher average vehicle ages.

Figure 16: Registered vehicles per capita in Maine municipalities (July 2020)

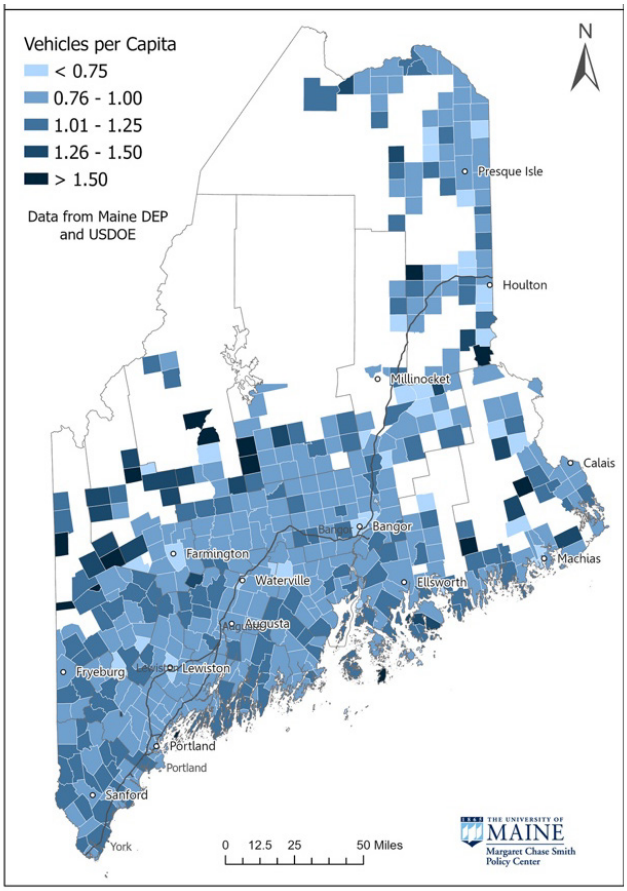
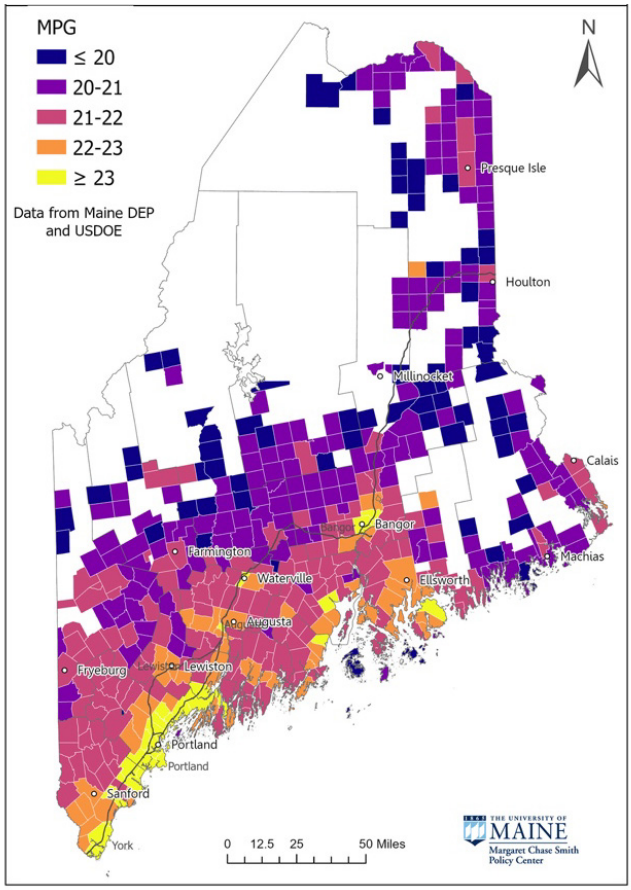


Figure 15: Average fuel efficiency (MPG) of vehicles registered in Maine (July 2020)



Indeed, Table 4 shows that rural areas have a higher percentage (10.3% vs 4.6%) of fuel inefficient vehicles (15 MPG or less) while urban areas have a higher percentage of hybrid and

electric vehicles with MPG of 40 or higher (1.3% vs 2.2%). Rural vehicles are also 2 years older on average. This supports the policy objective of increasing the proportion of newer, more fuel efficiency vehicles as a way to reduce transportation CO_2 emissions.

Table 4: Fuel efficiency: high and low MPG vehicles counts and percentages

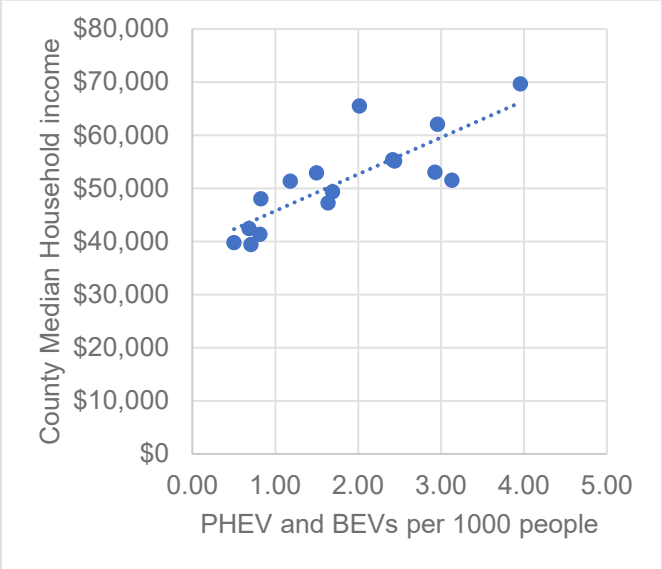
Municipal Type	Vehicle Registrations	Avg MPG	Below 15 MPG		Over 40 MPG	
			count	percent	count	percent
Rural	645,513	**21.3**	58,702	**10.3%**	7,255	**1.3%**
Town	252,618	**22.7**	13,695	**6.2%**	4,757	**2.1%**
Urban	294,412	**23.4**	11,995	**4.6%**	5,712	**2.2%**
Maine	1,192,543	**22.2**	84,392	**7.1%**	17,724	**1.5%**

Table 15 in Appendix B provides state and county level data on vehicle registrations per capita, vehicle age and average MPG.

Income and Hybrid/EV ownership

The distribution of PHEVs and BEVs throughout the state increases on a per capita basis in counties with higher median income, as shown in Figure 17. This is to be expected as new vehicles, representing roughly a third of all vehicle sales, are more frequently purchased by higher income households. As more used PHEVs and BEVs become available we would expect this relationship to change.

Figure 17: PHEV and BEVs per 1000 people, by median income



The median income by zip code is shown in Figure 18 below. The number of hybrids per 1000 people is shown in Figure 19, and the number of PHEVs and BEVs in Maine as of July 2020 are shown in Figure 20.

Figure 18: Median household income, 2014

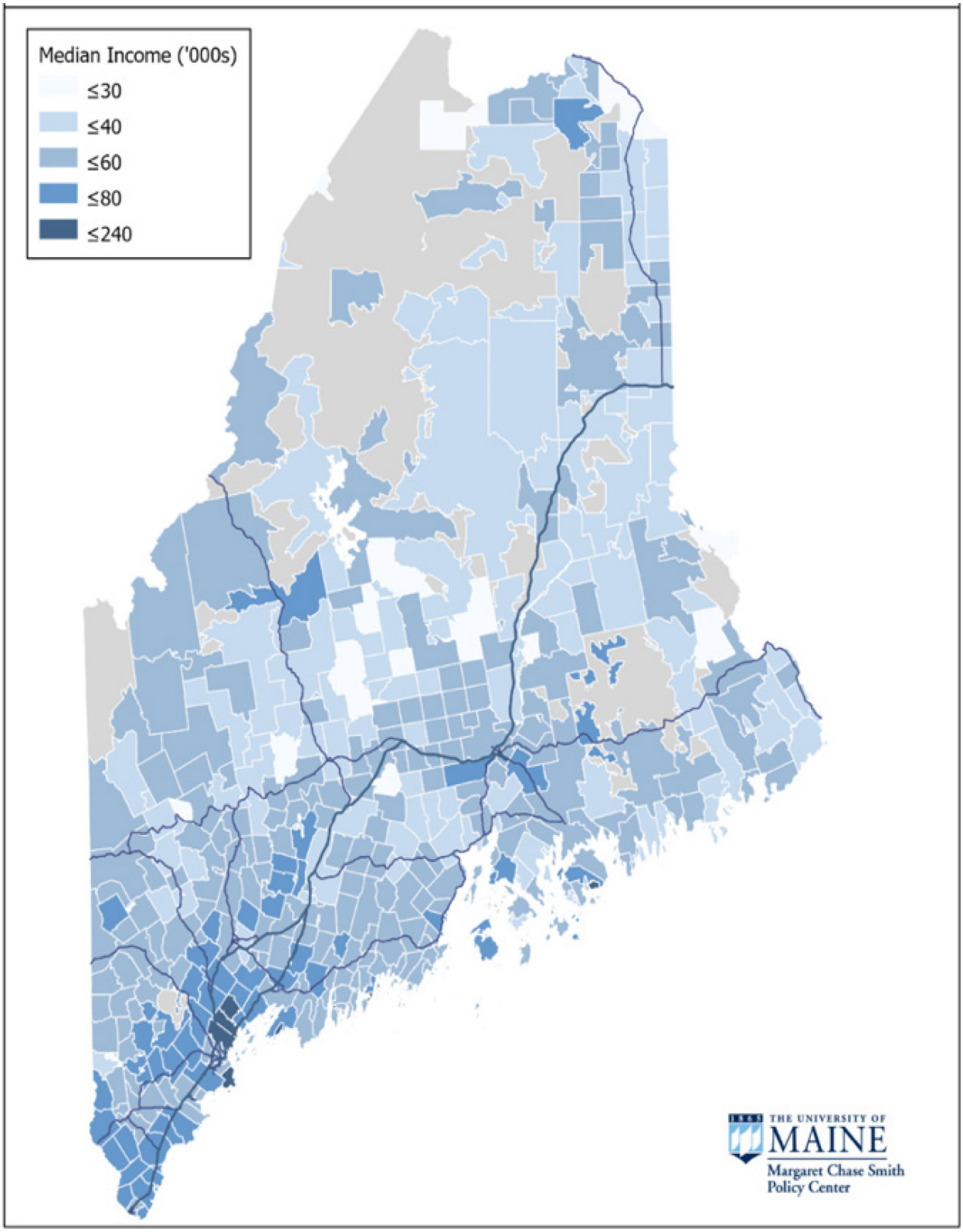


Figure 19: Hybrid vehicle ownership per 1000

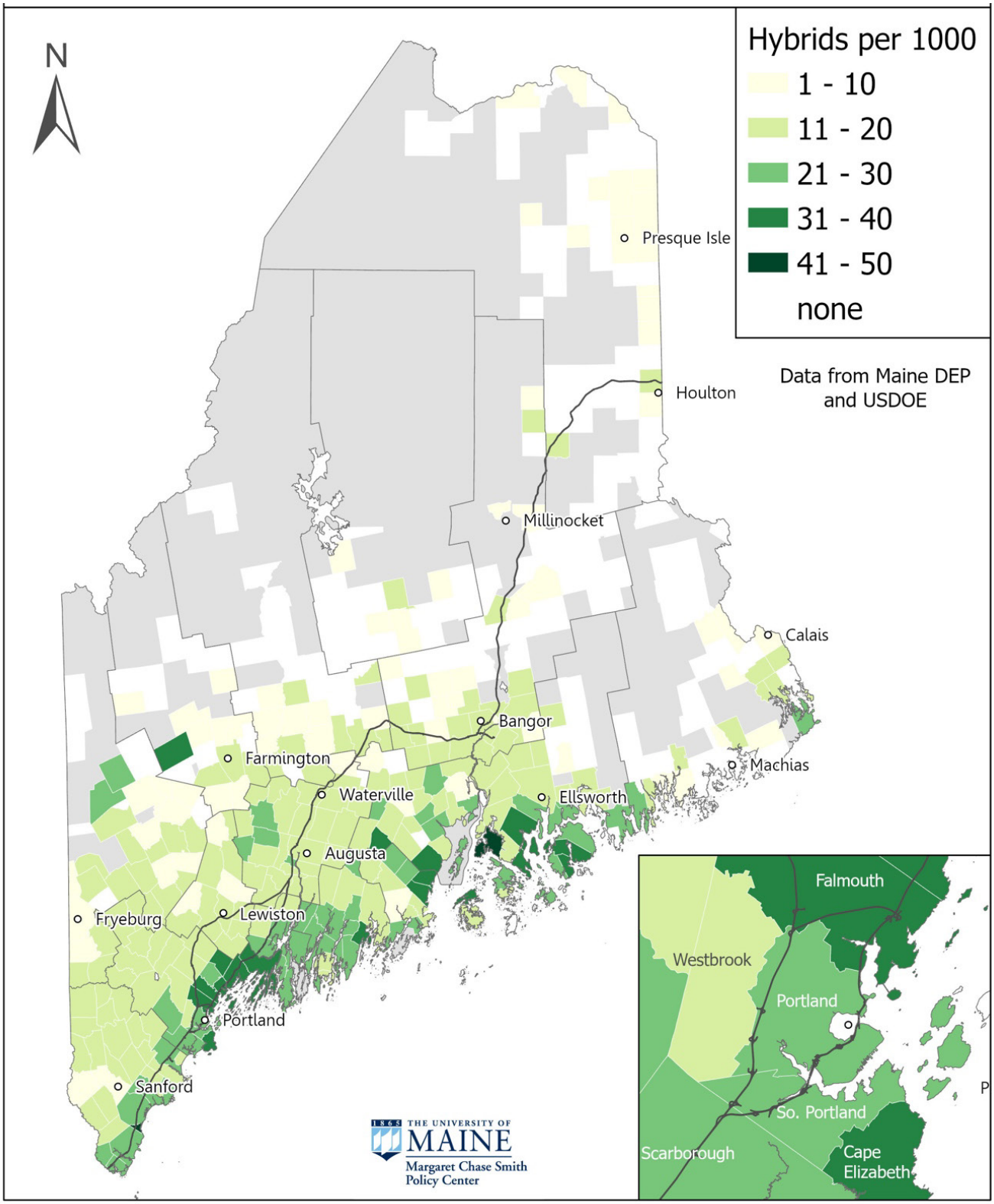
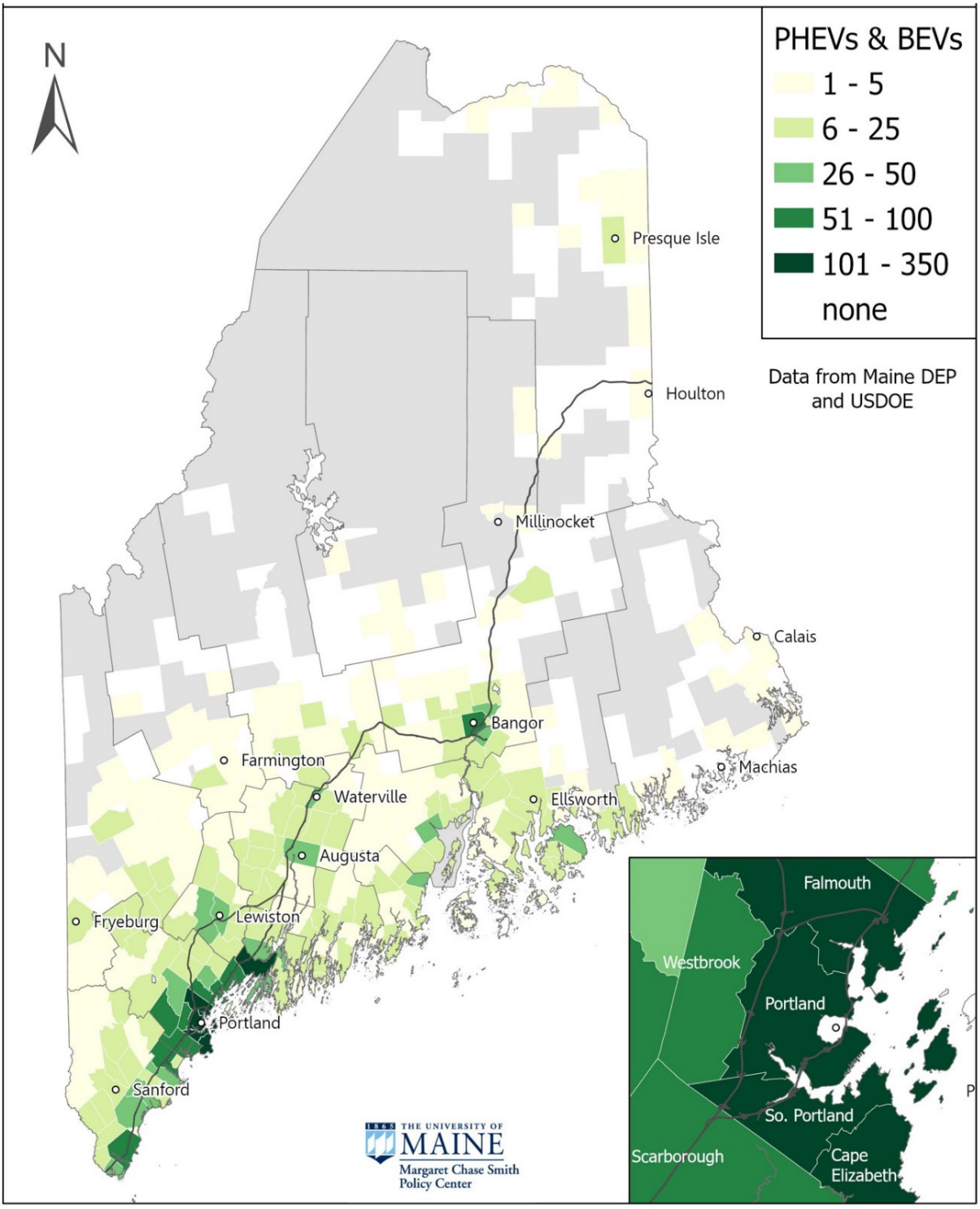


Figure 20: Plug-in hybrid and battery electric vehicles (July 2020)



Fuel and Emissions Savings Estimates for Used High MPG Vehicle Program

We estimate the environmental benefits and financial costs of an accelerated shift to newer and more fuel efficient vehicles on Maine's transportation emissions through a potential vehicle rebate program. For each, an average performing 10-year-old vehicle is assumed to be replaced by a newer more efficient used vehicle in the same vehicle class. We compare similar vehicles by size class and type because most consumers purchase replacement vehicles that are similar to their previous vehicles. Though consumers do switch vehicle types over time, most people purchase their next vehicle to perform similar services as the vehicle they are replacing. Drivers using a pickup truck, for example, will not generally find a compact sedan as an acceptable replacement vehicle.

The US DOE's Alternative Fuels Data Center provides a vehicle cost calculator that can compare the annual fuel use, fuel costs, operation costs and emissions generated for most vehicle models after 2005 (AFDC 2020). We use this calculator to compare the fuel cost and carbon dioxide (CO_2) emission savings from highly fuel efficient conventional and hybrid used vehicles as a replacement for older and less fuel-efficient vehicles. Choosing which used high-efficiency vehicles to include in a program requires judgement as to the best savings for the cost, based on vehicles that Maine drivers need and want.

The assumed rebate amount to the program participants is $2000. It has not yet been determined whether $2000 is an optimal amount to encourage moderate and low-income households to purchase newer, more efficient vehicles. To predict actual participation in a vehicle rebate incentive program requires constructing or parameterizing an existing vehicle choice model for Maine.[6]

Scenario 1: Popular Models

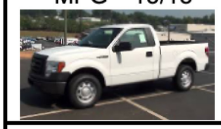
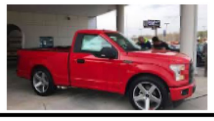
For the first scenario, 5 pairs of popular vehicle models of different size classes are compared and the reduction of fuel cost and CO_2 emissions savings are calculated for a 10 year period (see Figure 21). The highly fuel efficient conventional and hybrid used vehicles are all model years 2017, whereas the older and less fuel-efficient vehicles to be replaced are model years 2011. Fuel savings calculations include both the cost of gasoline and electricity, and assume that vehicles are driven 12,000 miles per year (close to the actual average miles per year for Maine). The cost of gasoline is assumed to be $2.80/gallon, and the cost and emissions factors for Maine's electric grid are set by the calculator tool.

The range of fuel CO_2 emissions reductions over a 10-year period for the 5 replacement pairs is 12.6 to 34.5 $MTCO_2$ (see Figure 21). The average reduction for all 5 pairs is 27.1 $MTCO_2$ over 10 years (see Table 6). The cost to the state of reducing a metric ton of CO_2 under these assumed scenarios is calculated by dividing the state's rebate by the average CO_2 savings over a 10-year

[6] See for example this recent comparison of vehicles choice models (Stephens, Thomas S. et al. 2017)

period. A $2,000 rebate results in a cost range of $58-158 / $MTCO_2$. This cost is equivalent to an average of 4.3¢/pound. The fuel cost savings over 10 years are also calculated to show the financial benefits to the owner, in addition to the rebate. The incremental cost of purchasing the new vehicle and the assumed reduction of maintenance costs have not been estimated, but are significant costs to the rebate program participants.

Figure 21: Vehicle replacement fuel & GHG savings over 10 years

Current Vehicle (2011)	Replacement Vehicle (2017)	Annual CO2 Reductions (lbs)	CO2 Savings over 10 years (MTCO2)	Annual Fuel Cost Savings @ $2.80/gal	Fuel Cost Savings over 10 years	Cost of a Metric Ton of CO2 ($/MTCO2)	Cost of a Metric Ton of CO2 ($/lbsCO2)
Ford F150 2WD (8 cyl.) MPG = 13/18 	Ford F150 2WD (6 cyl.) MPG = 19/26 	5753	26.1	$551	$5,510	$77	$0.035
Chevrolet Equinox AWD MPG = 20/28 	Toyota RAV 4 Hybrid AWD MPG = 34/30 	2783	12.6	$266	$2,660	$158	$0.072
Ford Fusion FWD MPG = 18/27 	Ford Fusion Enegri FWD Plug-in Hybrid MPGe = 88/ MPG 38 	6637	30.1	$288	$2,880	$66	$0.030
Toyota Corolla MPG = 26/34 	Toyota Prius Hybrid MPG = 54/50 	3924	17.8	$376	$3,760	$112	$0.051
Honda Fit MPG = 28/35 	Chevrolet Volt Plug-in Hybrid MPGe = 106 / MPG = 42 	7613	34.5	$188	$1,880	$58	$0.026

The assumption of the price of gasoline of $2.80/gallon is based on prices seen in the spring of 2021. If prices continue to increase in the post-pandemic recovery, the fuel cost savings to the vehicle owner will increase, see Table 5. The average additional cost savings for the vehicles in Figure 21, if gas prices increase from $2.80/gallon to $3.50/gallon or $4.00/gallon, are $362 and $620, respectively.

Table 5: Sensitivity of fuel cost savings to gasoline prices

Current Vehicle (2011)	Annual Fuel Use (gallon)	Replacement Vehicle (2017)	Annual Fuel Use (gallon)	Annual Fuel Savings @ $2.8/gallon	Annual Fuel Savings @ $3.5/gallon	Annual Fuel Savings @ $4/gallon
Ford F150 Pickup 2WD	767	Ford F150 Pickup 2WD	528	$935	$1,474	$1,858
Chevrolet Equinox AWD	496	Toyota RAV4 Hybrid AWD	382	$515	$863	$1,111
Ford Fusion FWD	432	Ford Fusion Energi Plug-in Hybrid	139	$813	$1,194	$1,466
Toyota Corolla	395	Toyota Prius Hybrid	233	$573	$850	$1,048
Honda Fit	376	Chevrolet Volt Plug-in Hybrid	31	$377	$641	$829

Assuming a rebate cost of $2,000 per vehicle, for every million dollars of funding for this program, 500 older vehicles could be replaced, eliminating an average of 13,550 metric tons of CO_2 over 10 years, and contributing a 0.03% annual reduction of Maine's 1990 levels of GHG emissions from light-duty vehicles (see Table 7, column 3). The cumulative GHG savings are shown in column 2 of Table 6.

Table 6: Used EV rebate program cost and benefits

Number of Rebates Issued	MT CO2 reduced over 10 years	Annual percent CO2 reduction over 1990 baseline for transportation (8,290,000 MT CO2)	Total Cost of Used EV Rebates
1	27.1	-	$ 2,000.00
500	13,550	0.03%	$ 1,000,000
2,000	54,200	0.11%	$ 4,000,000
5,000	135,500	0.27%	$ 10,000,000
10,000	271,000	0.54%	$ 20,000,000
20,000	542,000	1.09%	$ 40,000,000

Scenario 2: Average Maine Vehicles

A second scenario replaces the average 10 year-old vehicles in each type (Pickup, Minivan, SUV, Sedan, Hatchback) with the average of high efficiency vehicles of the same type. This may not represent the most likely replacement, but rather provides a better sense of the range in potential benefits and costs of the program. Three levels of replacement vehicles are the 'Top Runner' (1-4 years old gasoline vehicle in top 20% of fuel efficiency), average PHEV (1-4 years old) and the average BEV (1-4 years old). There are no PHEV or BEV models for Minivans and Pickups, so they are excluded from those scenarios.

The total CO_2 reductions of replacing the older vehicle with a top runner, used PHEV or BEV over the course of 10 years, with the same driving assumptions as the previous scenarios, are shown in Table 7. With an assumed rebate of $2,000, the range in cost to reduce emissions is \$91-\$344 /$MTCO_2$. The cost per metric ton of CO_2 improves significantly for used PHEVs and BEVs. The best performing scenarios for CO_2 reductions are:

- replacing a pickup with a top runner pickup;
- replacing an SUV or sedan with a used PHEV or BEV;
- replacing a hatchback with a used BEV.

Table 7: Top runner, PHEV, BEV scenarios

Vehicle Type	Old MPG	Top Runner			Used PHEV			Used BEV		
		New MPG	Annual gallons of fuel saved	Fuel cost savings *	New MPG	Annual gallons of fuel saved	Fuel cost savings *	New MPG	Annual gallons of fuel saved	Fuel cost savings *
Pickup	16	22	205	$5,727	NA			NA		
SUV	22	29	132	$3,687	66	364	$10,182	90	412	$11,539
Sedan	24	35	20	$4,400	66	245	$7,412	126	385	$11,333
Hatchback	28	35	86	$2,400	66	136	$3,805	115	324	$9,078
Minivan	20	22	55	$1,527	NA			NA		

** over 10 years @ $2.8/gallon*

Vehicle Type	Old MPG	Top Runner			Used PHEV			Used BEV		
		New MPG	$MTCO_2$ Saved **	\$/ $MTCO_2$	New MPG	MT CO2 saved **	\$/ $MTCO_2$	New MPG	MT CO2 saved **	\$/ $MTCO_2$
Pickup	16	22	21.8	$92	NA			NA		
SUV	22	29	14.0	$143	66	38.8	$52	90	43.9	$46
Sedan	24	35	16.8	$938	66	28.2	$77	126	43.1	$49
Hatchback	28	35	9.1	$219	66	14.5	$138	115	34.6	$58
Minivan	20	22	5.8	$344	NA			NA		

*** reduction over 10 years*

Programs Targeting Low-Income and Disadvantaged Households

A few states, Vermont, Pennsylvania, California, and Oregon, have new and used vehicle incentive programs specifically targeting lower income or otherwise disadvantaged households. California, with their historic and on-going leadership in clean transportation has several new and used vehicle incentive programs. Effective March 2016, and revised again in November 2016, the California Clean Vehicle Rebate Program (CVRP) was amended to include two income-based eligibility components: (1) an income cap that excludes high-income consumers from eligibility and (2) an increased rebate for consumers with household incomes less than or equal to 300% of the federal poverty level (which is defined each year and based upon household size). As long as funds are available, eligible California residents can follow a simple process to apply for a CVRP rebate after purchasing or leasing an eligible vehicle (Center for Sustainable Energy 2015).

The California Clean Cars 4 All, formerly EFMP (Enhanced Fleet Modernization Program) Plus-Up, provides an incentive for qualifying low-income individuals (those making up to 400% of the federal poverty level) who replace their old vehicle with a new or used hybrid, plug-in hybrid electric, or battery electric vehicle. In addition to income eligibility requirements, California also includes disadvantaged communities in the Clean Cars 4 All program. These communities include areas disproportionately affected by environmental pollution and other hazards that can lead to negative public health effects and areas with concentrations of people that are of low-income, high unemployment, low levels of home ownership, high rent burden, sensitive populations, or low levels of educational attainment.[7] Incentives are tiered, with those with the lowest income, purchasing PHEVs, EVs, or fuel cell vehicles, and living in disadvantaged communities receiving the highest amounts ("Clean Cars 4 All" n.d.).[8] Instead of purchasing a vehicle, participants may also choose to instead receive their incentive in the form of credits for alternative mobility options, such as transit passes or ride-shares (California Air Resource Board 2019). The program is administered by the participating air quality management districts and has slight variations in eligibility requirements between districts. However, the income requirements are the same in all districts. This program provides a model for an incentive program that aims to address equity issues in multiple parameters.

The State of Pennsylvania created the Alternative Fuel Vehicle Rebate program, launched on March 1st, 2020, with the goals of improving air quality, protecting the environment, and reducing dependence on oil imports (Pennsylvania Department of Environmental Protection 2020). The program provides rebates to consumers for the purchases of new and used alternative fuel vehicles, with an additional rebate for low income Pennsylvanians. The standard

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[7] 2 California Environmental Protection Agency. Designation of Disadvantaged Communities Pursuant to Senate Bill 535 (De Leon). Available at: https://calepa.ca.gov/envjustice/ghginvest/

[8] For the purposes of California clean vehicle incentive programs, low-income communities are defined as incomes at or below 80% of the statewide median income (California Air Resources Board 2018). Defined by AB 1550 (Gomez, Chapter 369, Statutes of 2016), the definition also allows for the California Department of Housing and Community Development to list a threshold of state income limits.

rebate ranges from $500 to $1,000, depending on the type of alternative fuel vehicle being purchased. Low income Pennsylvanians are eligible for an additional $1,000 rebate, on top of the standard rebate.

To specifically address the need for low and medium income individuals to have access to highly efficient vehicles, including new and used EVs and hybrids, Vermont created the Vermont Mileage Smart Program (State of Vermont Agency of Transportation 2020; MileageSmart 2020). Capstone Community Action launched this program on March 10, 2020. This program provides point-of-sale financial assistance to income-eligible Vermonters (at or below 80% median income, based on household size) to purchase used fuel-efficient vehicles. The MileageSmart incentive can contribute up to 25% toward the purchase of a used high MPG vehicle, up to $5,000 (MileageSmart 2020).

In addition to MileageSmart, Vermont also has an incentive program to assist income-eligible residents in the purchase of a new plug-in hybrid or electric vehicle. This program provides either point-of-sale or consumer-direct incentives, up to $4,000 (Drive Electric Vermont 2020). This program was originally launched in December of 2019 with $1,100,000 in funding; funds were depleted by October of 2020. On November 5th, 2020, the State of Vermont relaunched the incentive program with an additional $950,000 in funding. Incentives are tiered by income and tax filing status, with those making $50,000/year or less being eligible for the highest incentive amounts.

Oregon, like Vermont, has recognized the need for low and moderate-income households to have access to high efficiency vehicles. Oregon offers both a standard rebate, which applies to the purchase or lease of a new plug-in hybrid or electric vehicle by any Oregon resident, and the Charge Ahead rebate (Oregon Department of Environmental Quality 2020). The Charge Ahead rebate gives qualifying Oregonians $2,500 towards the purchase of a new or used plug-in hybrid or battery electric vehicle. To qualify, household income must be less than 120% of the median income for the nearest metropolitan statistical.

In Maine, the Electric Vehicle Rebate program, administered by Efficiency Maine, provides point-of-sale rebates to individuals, businesses, and organizations for the purchase of plug-in hybrid and electric vehicles (Efficiency Maine 2020). All Mainers are eligible for the standard rebate of $2,000 for a new electric vehicle or $1,000 for a new PHEV. Qualified low-income Mainers are eligible for an enhanced rebate of $5,500 for a new EV, $2,500 for a used EV, $4,000 for a new PHEV and $2,500 for a used PHEV (“Electric Vehicle Rebates” 2021).

To be eligible for the enhanced rebate, applicants must have qualified for the Maine Low Income Home Energy Assistance Program (LIHEAP) within the past 12 months. (“Form Seeking Pre-Approval of Qualified Low-Income Maine Resident Status” 2020). LIHEAP is a federal program designed to assist low-income households with home energy bills, weatherization, and energy crises (Division of Energy Assistance 2018b). To qualify, household income must be less than 150% of the federal poverty guidelines (FPG) or 60% of the state median income (Division of Energy Assistance 2018b). These figures are published annually by the Department of Health

and Human Services and are adjusted by household size (see Table 12 for Maine's 2020 guidelines).

Table 8: 2020–2021 Maine LIHEAP eligibility guidelines

Poverty Level	Household Size									
	1	2	3	4	5	6	7	8	9	10
1 Month	$2,344	$3,065	$3,787	$4,508	$5,229	$5,951	$6,086	$6,221	$6,356	$6,635
3 Months	$7,033	$9,197	$11,361	$13,525	$15,689	$17,853	$18,259	$18,664	$19,070	$19,905
12 Months	$28,133	$36,789	$45,445	$54,101	$62,757	$71,413	$73,036	$74,659	$76,282	$79,620

In 2018, approximately 30% of Maine households were eligible for LIHEAP and were therefore eligible for the additional rebate offered by Efficiency Maine. If Maine were to enact the same income eligibility requirements as the Vermont Mileage Smart program (80% of median income), an additional 11% of Maine households would be eligible for the increased rebate (Division of Energy Assistance 2018).

Table 9: 2018–2019 Maine LIHEAP eligibility guidelines (Division of Energy Assistance 2018a)

Est. Median Income for 4 Person Household	60% of Estimated State Median Income					
	1-Person	2-Person	3-Person	4-Person	5-Person	6-Person
$81,233	$25,345	$33,143	$40,942	$48,740	$56,538	$64,337

Table 10: Estimated percentage of population eligible for LIHEAP, by household size

Household size	Percentage
1 Person Household	14.42%
2 Person Household	8.85%
3 Person Household	2.69%
4 Person Household	2.08%
5 Person Household	1.16%
6+ Person Household	0.23%
Total Percentage of Population Eligible for LIHEAP	29.43%

Table 11: Estimated Percentage of Population: Incomes Less Than 80% Median Income

Household size	Percentage
1 Person Household	17.95%
2 Person Household	13.96%
3 Person Household	4.24%
4 Person Household	3.04%
5 Person Household	1.39%
6+ Person Household	0.96%
Total Percentage Under 80% Median Income	41.53%

Financing Assistance for Lower-Income Consumers

Financial incentives can play an important role in lowering Maine's fuel costs and GHG emissions by accelerating the retirement and replacement of older, high GHG emitting vehicles and increasing the adoption of fuel efficient and low GHG emission vehicles. In response to a low participation in California's Clean Vehicle Rebate Program by low and moderate income households, the California Air Resources Board created the Plus-Up pilot program (now known as Clean Cars 4 All) as an additional replacement incentive depending on household income and type of replacement vehicle for the purchase or lease of a new or used "clean vehicle." Clean vehicle *financing* programs, as distinct from purchase price *incentive* programs, are more recent in nature and limited in scope (Pierce et al. 2019).

CARB continues to expand incentives to increase participation by low-income residents including financing mechanisms for new and used vehicles, consumer pre-qualification for point-of-sale incentives, and increasing the rebate incentive for low-income consumers to purchase or lease a clean vehicle. Vehicle financing can be a significant barrier to vehicle ownership for lower income consumers, especially for the purchase or lease of zero-emission vehicles which have higher upfront costs. (California Air Resources Board 2018). The Clean Vehicle Financing Assistance Program includes vehicle buy-down grants (pre-approved, point-of-sale grants) and low-cost consumer loans subsidized via a loan-loss reserve program.

Loan Loss Reserve (LLR) programs provide loan loss coverage to financing partners such as local and regional banks and credit unions. LLR programs, used in clean energy financing, are a form of credit enhancement that can be constructed to offer below-market-rate terms to increase participation. If a borrower defaults on a loan, the loan loss reserve will reimburse the lender, up to an agreed amount of risk sharing with the private lender (ACEEE 2020). A state can allocate a set amount of capital and work with a private sector financial partner to determine the size of the loan portfolio based on risk, interest rates, other institutional goals such as income eligibility and repayment terms. With a 20:1 leverage ratio, a $1 million state investment can support up to $20 million in loans on a revolving basis.[9]

[9] ACEEE gives details on LLR programs in Connecticut, Michigan and California.

Scrappage of old high-emitting vehicles

In addition to encouraging Maine residents to upgrade older, less fuel-efficient vehicles, vehicle scrappage programs give a cash incentive to scrap older, high emitting vehicles. Maine previously had a pilot program for the retirement of high-pollution vehicles by providing owners with incentives for scrapping these vehicles and purchasing cleaner vehicles (see Appendix for the full text). We view a scrappage program as an essential component to a used high MPG program. The precise mechanism of linking a used high MPG program with a scrappage program needs careful consideration and impact the costs of each program and the carbon savings.

Maine's (discontinued) Scrappage Program

The program began on November 1, 2000 and was repealed November 1, 2003. This voluntary program provided owners of high pollution vehicles with a cash incentive to retire (or "scrap") their vehicle and replace it with a 4-year-old or later model year vehicle that is certified as either a National Low Emission Vehicle, or as a Low Emission Vehicle, Ultra Low Emission Vehicle, Super Low Emission Vehicle, or Zero Emission Vehicle under the California Low Emission Vehicle Program. A review of the program found that it was highly popular with the public with two notable limitations (Cayting, Lynne 2003). The program was funded initially at $110,000 allowing for 80 vouchers to be claimed but left a backlog of 900 applicants on the waiting list without funding. Secondly, the scrap program specified that scrapped vehicles by *automotive recyclers*, as opposed to scrapyards or junkyards, due to their higher level of environmental regulation. The Maine Auto Recyclers Association testified that auto recyclers would incur a cost of $350 - $500 (in 2000) which exceeded the value of sale of vehicle parts and crushed metal from the scrapped vehicles.

US Experience with Scrappage

In 2009, the United States enacted a nationwide scrappage program. Amid the Great Recession, the Consumer Assistance to Recycle and Save Act (CARS) was enacted, as part of the Supplemental Appropriations Act (*Consumer Assistance To Recycle and Save Act of 2009* 2009; *Requirements and Procedures for Consumer Assistance To Recycle and Save Program* 2009). The program started on July 1st and was designed to run until November 1st, 2009, or until the funds were depleted. Under this program, vehicle owners could trade in old, inefficient vehicles for scrap and receive a credit towards a new, more efficient vehicle. This program allowed the trade-in of eligible vehicles from four different classes: passenger vehicles, category 1 trucks (SUVs, minivans, small and medium pickup trucks, etc.), category 2 trucks (large vans or pickup trucks) and category 3 trucks (pickup trucks or cargo vans weighing between 8,500 and 10,000 pounds). To be eligible for trade-in, passenger vehicles, category 1 trucks, and category 2 trucks had to have a mileage rating of 18 MPG or less and be no more than 25 years old.

Rebates were determined based on the difference in fuel efficiency between the trade-in vehicle and the new vehicle. For passenger vehicles, for example, to receive the full rebate amount of $4,500 required a 10 MPG fuel efficiency increase. An increase of 4-9 MPG would result in a reduced rebate of $3,500. The full list of incentives for passenger automobiles, category 1 trucks, and category 2 trucks can be found in Table 12. By the end of July, the initial

$1 billion in funding had been spent. Congress allocated an additional $2 billion to the program to help sustain it (Wald 2009). On August 25th, 2009, the program was ended, with about 700,000 vehicles scrapped and a 58% increase in fuel economy in the participant vehicle fleet (Bolton 2009).

Table 12: Required difference in fuel efficiency between trade-in vehicle and new vehicles

Trade-In Vehicle[10]	New Vehicle	Increase in MPG for $3,500 Incentive	Increase in MPG for $4,500 Incentive
Passenger Automobile	Passenger Automobile	4–9 MPG	≥ 10 MPG
Category 1 Truck	Passenger Automobile	4–9 MPG	≥ 10 MPG
Category 2 Truck	Passenger Automobile	4–9 MPG	≥ 10 MPG
Passenger Automobile	Category 1 Truck	2–4 MPG	≥ 5 MPG
Category 1 Truck	Category 1 Truck	2–4 MPG	≥ 5 MPG
Category 2 Truck	Category 1 Truck	2–4 MPG	≥ 5 MPG
Category 2 Truck	Category 2 Truck	1 MPG	≥ 2 MPG

While the program was undeniably popular with the public, a review of the literature shows varying GHG reductions and a wide range of cost per ton abated estimates. Lenski et. al. conducted a life cycle analysis and found that the program created a one-time reduction of 4.4 million metric tons of CO_2 equivalent, equal to 0.4% of annual light-duty vehicle emissions (Lenski, Keoleian, and Bolon 2010). This is equal to a cost per metric ton abated of about $630. Additionally, they also found that 0.8 million metric tons were emitted, as a result of early scrappage and replacement. Li et. al. used a difference-in-difference analysis, with Canada as the control country, to estimate the reduction in GHG emissions due to the program. They estimated that the program resulted in the abatement of 9-28.2 million tons, for a cost per ton abated of $92-$288 (Li, Linn, and Spiller 2013). However, they believe that about 45% of the incentives went to consumer who would have purchased new vehicles, regardless of the rebate program. This indicates that a more targeted approach may provide a more cost-effective reduction in GHG emissions.

[10] Requirements and Procedures for Consumer Assistance to Recycle and Save Program (Bolton 2009b).

Final Comments

Despite fuel efficiency improvements across all vehicle types, Maine's average fuel efficiency has not increased since 2015. This is due to a change in customer preferences for larger SUVs, as well as increased longevity of vehicles. This trend, along with low uptake of new electric vehicles will pose a challenge to meet GHG reduction goals in the transportation sector. Thus, policies and programs that will accelerate the shift to lower emissions vehicles should be considered.

We provide estimates of possible fuel and GHG savings from a used high MPG vehicle incentive program for Maine. We compare 5 popular vehicle models of different size classes with newer, more fuel efficient, but comparable vehicles. The highly fuel efficient conventional and hybrid used vehicles are all model years 2017, whereas the older and less fuel-efficient, but similar, vehicles are model years 2011. Fuel savings calculations include both the cost of gasoline and electricity, and assume that vehicles are driven 12,000 miles per year and gasoline is at 2.80/gallon. We estimate that the 5 replacement pairs save between 12.6 to 34.5 $MTCO_2$ over 10 years. The average reduction for all 5 pairs, is 27.1 $MTCO_2$ over 10 years. The cost to the state of reducing a metric ton of CO_2, calculated by dividing a $2,000 rebate by the average CO_2 savings, 27.1 $MTCO_2$, ranges from $58-158 / $MTCO_2$. This cost is equivalent to an average of 4.3¢ /pound. The GHG emission reductions realized will depend on the specifics of the program implementation, the willingness of consumers to use the program, and the linkage of such a program with a scrappage program to remove the least efficient vehicles from Maine's roads.

Efficiency Maine currently offers enhanced rebates for new and used EVs for qualified low income households. We estimate that approximately 30% of Maine households are eligible for these enhanced rebates based on Efficiency Maine's income guidelines (based on LIHEAP eligibility). If Maine were to enact the same income eligibility requirements as the Vermont Mileage Smart program (80% of median income), an additional 11% of Maine households would be eligible for the increased rebate. Loosening the eligibility would increase the program's costs.

Because middle- and lower-income individuals may not have access to low-cost conventional automobile loans, we recommend that Maine consider setting up a publicly funded loan loss reserve (LLR) program. LLRs provide loan loss coverage to financing partners such as local and regional banks and credit unions. These programs are a form of credit enhancement to offer below-market-rates to increase the affordability of higher fuel economy used conventional and electric vehicles to identified groups to enhance social equity.

Limitations and Further Research

Our analysis of Maine's vehicle fleet is based on anonymized records by zip code. As such, we are not able to link household characteristics (income, race, education, attitudes) to specific vehicles. This limits our ability to make forecasts on how changes in vehicle and fuel prices and attitudes about EVs and EV charging availability will impact changes in vehicle turnover, fuel use and GHG emissions.

To reduce GHG emissions from the Maine's light-duty vehicle fleet also requires speeding up the retirement of inefficient (high fuel use per mile) vehicles in regular use. This requires a more careful examination of low fuel economy vehicles in terms of who uses them and for what purposes. To ensure that all households have access to newer, more reliable, fuel efficient vehicles, we need to further examine the best practices that address the financial needs of middle and lower-income households such as a loan loss reserve program. Additionally, we need to further research how best to serve different types of households who have different needs and levels of interest and engagement in reducing GHG emissions.

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Appendix A: Additional Tables and Figures of Maine's Vehicle Fleet

Table 13: Top Vehicles in Maine by Age and Fuel Efficiency

MAKE & MODEL	AvgAge	AvgMPG	AvgGPM	Registered
CHEVROLET Silverado	10.4	16.3	61.7	48,340
FORD F-150	10.3	16.9	60.4	40,987
GMC Sierra	11.5	16.2	62.3	36,009
SUBARU Forester	8.5	24.5	41.5	28,596
TOYOTA RAV4	7.2	25.4	40.0	28,458
HONDA CR-V	8.5	25.6	39.5	25,051
TOYOTA Tacoma	9.3	19.3	51.8	24,793
SUBARU Outback	8.2	23.6	42.7	24,233
TOYOTA Camry	12.0	25.0	40.9	23,871
TOYOTA Corolla	10.5	29.2	34.4	21,048
FORD Escape	7.6	23.4	43.2	21,003
TOYOTA Tundra	10.1	15.6	64.3	17,393
JEEP Grand Cherokee	10.9	17.8	57.1	17,116
FORD Focus	9.8	28.6	35.1	16,690
HONDA Civic	11.1	31.1	32.5	16,370
JEEP Wrangler	12.7	16.8	60.0	16,084
HONDA Accord	12.0	25.6	40.0	14,140
NISSAN Rogue	5.5	26.9	37.4	13,957
SUBARU Impreza	8.6	26.4	39.1	13,629
RAM 1500	4.3	18.4	54.6	13,597

Table 14: Rate of Hybrid and EV ownership in Maine townships

Class	HEV	PHEV	BEV	ALLHEV	Population	HEVs per 1000 people	PHEV + BEV per 1000 people
Rural	9,528	941	522	10,991	644,295	14.8	2.3
Town	5,895	632	466	6,993	284,504	20.7	3.9
Urban	6,921	763	417	8,101	366,940	18.9	3.2
Maine	22,344	2,336	1,405	26,085	1,295,739	17.2	2.9

Table 15: County Vehicle Registration Statistics

County	Population	Most Popular Vehicle	Average Age	Average MPG	Vehicles Registered	Vehicles per Capita
Androscoggin	107,317	Silverado	10.6	22.3	82,815	0.77
Aroostook	67,637	Sierra	10.7	21.0	52,236	0.77
Cumberland	289,173	Forester	9.4	23.6	245,026	0.85
Franklin	30,177	F-150	11.5	21.1	23,748	0.79
Hancock	54,468	Silverado	10.7	22.2	48,227	0.89
Kennebec	121,289	Silverado	10.5	22.3	100,805	0.83
Knox	39,700	Silverado	10.9	22.2	34,012	0.86
Lincoln	34,021	Silverado	11.2	22.0	31,677	0.93
Oxford	57,230	Silverado	11.7	21.4	48,513	0.85
Penobscot	151,050	Silverado	10.0	22.2	116,684	0.77
Piscataquis	16,960	Silverado	11.6	20.8	13,579	0.80
Sagadahoc	35,149	Forester	10.4	22.8	30,938	0.88
Somerset	50,994	Silverado	11.4	21.1	41,122	0.81
Waldo	38,453	Silverado	11.5	22.2	33,715	0.88
Washington	31,822	Silverado	11.0	21.0	24,531	0.77
York	201,454	Silverado	10.0	22.8	183,101	0.91
unmatched	NA	F-150	11.5	20.9	11,159	NA
Maine	1,326,894				1,121,888	0.85

Table 16: BEVs registered in Maine, July 2020

Make	Model	Registered
NISSAN	Leaf	398
TESLA	Model 3	356
CHEVROLET	Bolt EV	225
TESLA	Model S	144
HYUNDAI	Kona	73
TESLA	Model X	58
VOLKSWAGEN	e-Golf	42
HYUNDAI	Ioniq	28
FORD	Focus	11
KIA	Niro	9
MITSUBISHI	i-MiEV	9
SMART	EQ Fortwo	8
SMART	Fortwo	8
SMART	Fortwo Electric Drive	8
AUDI	e-tron	6
JAGUAR	I-PACE	6
FIAT	500	6
BMW	i3	5
KIA	Soul	4
BMW	i3	4
CHEVROLET	Spark	4
TESLA	Model Y	2
MITSUBISHI	Outlander Sport	1
MERCEDES-BENZ	B-Class	1
FORD	Focus	1

Table 17: Plug-in Hybrid Vehicles Registered in Maine, July 2020

Make	Model	Registered
TOYOTA	Prius Prime	642
FORD	Fusion	386
CHEVROLET	Volt	383
FORD	C-max	222
TOYOTA	Prius Plug-in	169
TOYOTA	Prius Plug-in	134
HONDA	CLARITY	130
HYUNDAI	Ioniq	66
SUBARU	Crosstrek	56
CHRYSLER	Pacifica	31
BMW	X5	29
BMW	i3	24
VOLVO	XC90	15
HYUNDAI	Sonata	13
BMW	i3	9
AUDI	A3	8
AUDI	A3 Sportback e-tron	5
PORSCHE	Cayenne	4
MERCEDES-BENZ	GLC-Class	3
MERCEDES-BENZ	GLE-Class	3
KIA	Optima	3
CADILLAC	ELR	2
PORSCHE	Panamera	2
AUDI	Q5 e	1
HONDA	Accord	1
CHEVROLET	Malibu	1
MERCEDES-BENZ	S-Class	1
VOLVO	S90	1

Table 18: Number of Hybrids, PHEVs and BEVs in Maine, July 2020

Make	Model	Registered
TOYOTA	Prius	9365
TOYOTA	RAV4 Hybrid	2048
TOYOTA	Camry Hybrid	1295
TOYOTA	Prius C	1106
FORD	Fusion	1011
TOYOTA	Highlander	934
TOYOTA	Prius V	918
HONDA	Civic Hybrid	564
CHEVROLET	Silverado	502
LEXUS	RX	447
FORD	C-max	441
HONDA	Insight	370
GMC	Sierra	347
FORD	Escape	298
HYUNDAI	Sonata	280
HONDA	Accord	275
TOYOTA	Avalon	233
NISSAN	Altima	205
SUBARU	Crosstrek	165
KIA	Optima	150
KIA	Niro	141
LEXUS	CT	129
HONDA	Insight	106
HONDA	CR-Z	101
HYUNDAI	Ioniq	92
TOYOTA	Corolla	86
LINCOLN	MKZ	79
CHEVROLET	Avalanche	68
LEXUS	ES	67
CHEVROLET	Tahoe	62
CHEVROLET	Suburban	58
VOLKSWAGEN	Jetta	57
CHEVROLET	Malibu	45
MERCURY	Mariner	35
SATURN	Vue	33
GMC	Yukon	31

LEXUS	NX	28
LEXUS	HS	25
LEXUS	UX	22
CHRYSLER	Pacifica	22
BUICK	LaCrosse	20
FORD	Explorer	19
GMC	Yukon XL	19
NISSAN	Rogue	17
MITSUBISHI	Outlander - PHEV	16
LAND ROVER	Range Rover Sport	14
INFINITI	Q50	14
NISSAN	Pathfinder	13
BMW	530e	10
CHEVROLET	Express	9
CADILLAC	Escalade	9
ACURA	MDX	8
MERCURY	Milan	8
MINI	Cooper S Countryman	7
AUDI	Q5	7
LAND ROVER	Range Rover	6
HONDA	CR-V	5
GMC	Envoy	5
VOLVO	XC60	5
PORSCHE	Cayenne	4
INFINITI	QX60	4
BMW	330e	4
SATURN	Aura	4
LEXUS	GS	4
LEXUS	LS	4
ACURA	RLX	4
GMC	Savana	3
NISSAN	Murano	3
VOLVO	XC90	2
SAAB	9-7X	1
CHRYSLER	Aspen	1
CHEVROLET	Trailblazer	1
BMW	X6	1
BMW	i8	1
MERCEDES-BENZ	S-Class	1

Appendix B: Maine' High Polluting Vehicle Retirement Program (Discontinued)

Chapter 147: HIGH POLLUTION VEHICLE RETIREMENT PILOT PROGRAM

SUMMARY: This regulation establishes a pilot program for the retirement of high-pollution vehicles by providing owners with incentives for scrapping these vehicles and purchasing cleaner vehicles.

1. **Scope/Applicability.** This regulation applies statewide.

2. **Definitions**

   A. **Authority.** "Authority" means the Finance Authority of Maine.

   B. **Automobile Scrapper**. "Automobile scrapper" means an automobile graveyard, an automobile recycling business or a junkyard, as those terms are defined in 30-A, M.R.S.A §3752, which is duly-permitted to operate pursuant to 30-A M.R.S.A. §§ 3753-3760.

   C. **Certificate of Verification.** "Certificate of Verification" means a certificate issued by the automobile scrapper who receives and scraps a high-pollution vehicle.

   D. **Cleaner vehicle.** "Cleaner vehicle" means a vehicle that:

      (1) Is a model year 1996 or later; and

      (2) The Vehicle Emission Control Information label under the hood or Manufacturer's Certificate of Origin (MCO) which certifies that the vehicle is a National Low Emission Vehicle (NLEV) pursuant to 40 CFR Parts 9, 85 and 86 as amended January 7, 1998; or a Low Emission Vehicle (LEV), Ultra Low Emission Vehicle (ULEV), Super Low Emission Vehicle (SULEV), or Zero Emission Vehicle (ZEV) as defined by Title 13, California Code of Regulations, Section 1960.1(g)(1) and incorporated by reference herein.

   E. **Deliver.** "Deliver" means to transfer ownership of a vehicle.

   F. **Eligible seller.** "Eligible seller" means a Maine resident or a vehicle dealership authorized to do business in this State.

   G. **Fund.** "Fund" means the Clean Fuel Vehicle Fund established under 10 M.R.S.A. Section 1023-K.

   H. **High-pollution vehicle.** "High-pollution vehicle" means a car or truck with a gross vehicle weight rating of 6,000 pounds or less that:

(1) Is a model year 1987 or older;

(2) Has been registered in this State for the last 24 months; and

(3) Is presently operational and is driven under its own power to the site where it is scrapped.

I. Incentive Voucher. "Incentive Voucher" means a voucher issued by the Department to the owner of a high-pollution vehicle redeemable upon purchase of a cleaner vehicle, if the owner submits a Certificate of Verification that the high-pollution vehicle was scrapped.

J. Letter of Assurance. "Letter of Assurance" means a letter from the Department to an owner who intends to scrap a high pollution vehicle which shall entitle the owner to an incentive voucher upon presentation to the Department of a Certificate of Verification and compliance with all other program requirements. A letter of assurance does not create any property interest in the recipient, shall be issued only to the extent of available financing in the Fund, and shall not create any entitlement to reimbursement from any source other than the Fund.

K. Person. "Person" means any individual, partnership, corporation, whether private, public or quasi-municipal, municipality, state governmental agency or other legal entity.

L. Scrap. "Scrap" means permanently dismantling a vehicle and destroying the engine. "Scrap" may include salvaging and using parts of the vehicle other than the engine.

3. Establishment of a High-Pollution Vehicle Retirement Pilot Program

A. The Department shall maintain a list of automobile scrappers who have volunteered to participate in the Program and are permitted by their municipality. The participating automobile scrapper must submit a signed statement that they are in compliance with that permit and all municipal ordinances, and state and federal laws and regulations. A copy of the signed statement shall be sent to the municipality. Pursuant to this Chapter, high polluting vehicles can only be scrapped by participating and compliant automobile scrappers.

B. To the extent of available financing in the Fund, the Department may issue Letters of Assurance on a first come, first serve, basis to owners who intend to scrap high pollution vehicles. To obtain a Letter of Assurance, the owner of the high pollution vehicle shall provide proof that the vehicle was registered for the previous 24 months; along with year, gross vehicle weight, the make, model and number of cylinders of the vehicle. At that time, subject to availability of funds, the Department will issue a Letter of Assurance informing the owner of the amount of money for which he/she is eligible based upon the type of vehicle to be scrapped. The Letter of Assurance will expire 90 days from the date of issuance; upon expiration, the high pollution vehicle owner must contact the Department to request a new Letter of Assurance.

C. When a Letter of Assurance is issued, the Department shall post on the Department's web site information on the vehicle being scrapped. This notice will be posted by the Department on a weekly basis.

D The owner of a high pollution vehicle shall provide the automobile scrapper with a Letter of Assurance from the Department at the time the vehicle is delivered for scrapping.

E. When a high pollution vehicle is delivered for scrapping, the automobile scrapper shall provide the owner with a Certificate of Verification that includes the following information:

(1) The date that the high-pollution vehicle was surrendered to the automobile scrapper;

(2) Certification that the vehicle was operational and driven under its own power to the site where it was scrapped.

(3) The Vehicle Identification Number (VIN);

(4) The vehicle odometer reading at the time it was scrapped;

(5) Vehicle model year;

(6) Vehicle make, model and number of cylinders;

(7) Name, address and phone number of registered owner;

(8) Name and location of the automobile scrapper;

(9) Signature of the automobile scrapper certifying the accuracy of the above information.

F. To the extent funds are available in the Fund, the Department shall pay a permitted and compliant automobile scrapper up to $350 for each high-pollution vehicle scrapped under the program. Payments must be made directly to the automobile scrapper upon receipt of an invoice and a certificate of verification that the high-pollution vehicle was scrapped.

G. Subject to the availability of funds, the Department shall issue an Incentive Voucher when the owner of the high polluting vehicle provides the Department with a Certificate of Verification issued pursuant to sub-section Section 3(E) of this Chapter. The voucher shall state its value in accordance with Section 4 of this Chapter; and that the voucher's date of expiration shall be 90 days from the date of issuance of the voucher by the Department, but no later than October 1, 2003. The voucher shall be clearly marked with the expiration date. The Department shall issue vouchers only to the extent funds are available in the Fund.

H. The eligible seller shall complete the Incentive Voucher issued to the purchaser. The completed voucher must include:

(1) Name, address and phone number of the purchaser;
(2) Vehicle make, model and model year of the cleaner vehicle;
(3) The actual certification of the cleaner vehicle, for example LEV, ULEV;
(4) The seller's name, address and phone number; and
(5) Signature of the eligible seller.

I. Using money available in the Fund, the Authority shall redeem for face value any completed Incentive Voucher prior to the date of expiration.

J. No person shall be issued more than one Incentive Voucher per year.

K. Incentive Vouchers may be transferred and combined.

4. Incentive Voucher Amounts

The Department shall issue Incentive Vouchers with the following values for the following types of high-pollution vehicles:

A. A voucher worth $1,500 for a pickup truck or sport utility vehicle with a 6-cylinder engine;

B. A voucher worth $2,000 for a pickup truck or sport utility vehicle with a 8-cylinder engine; and

C. A voucher worth $1,000 for any other high-pollution vehicle.

5. Effectiveness report

At the end of each calendar year, no later than February 15 of the subsequent calendar year, the Department shall submit a report to the joint standing committee of the Legislature having jurisdiction over natural resource matters that:

A. Analyzes the strengths and weaknesses of the program;

B. Provides a thorough assessment of the costs and the short-term and long-term emission reduction benefits of the program, based on best estimates of the emission characteristics of vehicles scrapped and purchased under the program, compared with other vehicle-related emission reduction programs adopted by the State; and

C. The final report shall include an evaluation of whether the program should be continued.

6. Effective Date. This program shall become effective November 1, 2000 and shall expire November 1, 2003.

7. Repeal. This rule is repealed November 1, 2003.

AUTHORITY: 5 M.R.S.A. Section 8052
38 M.R.S.A. Section 341-D, subsection 1-B
10 M.R.S.A. Section 394 et seq.

EFFECTIVE DATE: November 1, 2000
Amended: November 13, 2001

BASIS STATEMENT

Beginning November 1, 2000, the High Pollution Vehicle Retirement Pilot Program was established by the Legislature to provide owners of high-pollution vehicles with incentives for scrapping these vehicles and purchasing cleaner vehicles. The Legislature required that the Department adopt rules implementing this Program and establish by rule procedures to ensure that a person who intends to scrap a high- polluting vehicle can obtain from the Department written assurance that upon submission of a certificate of verification the person will be issued an incentive voucher redeemable upon purchase of a cleaner vehicle.

The rule will reduce both ozone-forming and toxic emissions by removing older high-polluting vehicles from the road and replacing them with newer less-polluting vehicles.

In addition to the Basis Statement above, the Department has filed with the Secretary of State its response to comments received during the public comment period.

BASIS STATEMENT FOR OCTOBER 18, 2001

Chapter 147 was amended to reflect legislation, which allowed high pollution vehicles to be scrapped at permitted automobile graveyards, junkyards, as well as automobile recyclers. In addition, this legislation authorized FAME to compensate permitted automobile scrappers up to $350 for each high-polluting vehicle scrapped under the Program.

In addition to the Basis Statement above, the Department has filed with the Secretary of State its response to comments received during the public comment period.

Appendix C: Fuel and Emissions Calculations

- Vehicle data on fuel use and CO2 emissions comes from the AFDC Vehicle cost calculator.
- Assumptions used for calculator:
    - Years used vehicle will be in operation: 10 years
    - Rebate Amount per vehicle: $2000
    - lbs of CO2 to Metrics tons conversion factor: 0.000453592
- Driving Profile:
    - Annual Driving Distance: 12000 miles
    - (City Distance 4800 miles/ Highway Distance 7200 miles)
    - Normal Daily Use:
        - Daily distance: 40 miles
        - Days per week: 5
        - Weeks per year: 50
        - Percent highway: 60
    - Other Trips:
        - Annual mileage: 2000 miles
        - Percent highway: 60

Carbon Dioxide Emissions from Fossil Fuel Combustion (From DEP spreadsheet: Transportation MMTCO2.xlsx)	
MMTCO2 Transportation	**1990**
Gasoline Light-duty vehicles	4.90
Gasoline Heavy-Duty Vehicles	0.29
Gasoline Motorcycles	0.01
Diesel Light-duty vehicles	0.07
Diesel Heavy-Duty Vehicles	1.47
Aviation	1.06
Boats	0.21
Locomotives	0.05
Other	0.23
Alternative Fleets	0.00
Total	8.29