A Pileup

Surface Transportation Market Failures and Policy Solutions

Institute *for* Policy Integrity
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Executive Summary

Surface transportation, the movement of people or goods in cars, trucks, trains, buses, and subways, in the United States is in need of reform. The corresponding greenhouse gas (GHG) emissions, local air pollution, traffic congestion, and traffic collisions from cars and trucks generate billions of dollars in economic harm every year.

Each on these harms is caused by a *market failure*, where market forces alone lead to a sub-optimal outcome.[1] Policymakers have an important role to play in such a setting, as well-designed policies can align incentives so as to mitigate the harms of market failures and increase the quality of life for constituents – all at a lower cost to society than the existing paradigm.

This report serves as a reference for policymakers and stakeholders interested in reforming the transportation sector with a particular focus on road-way travel – the venue for nearly 99 percent of all miles traveled in 2018.[2] This report begins by describing the major transportation market failures, including their determinates, magnitude, and incidence.[3]

Guided by economic principles, this report summarizes the well-established economically efficient policy solutions and outlines several options for reforming surface transportation that account for technological, institutional, and political realities. Finally, this report highlights the unequal burden of market failures in the transportation sector and policy solutions that can help lead to a more just outcome.

Externalities in the Surface Transportation Sector

Greenhouse-gas emissions – If left unabated, GHG emissions will contribute to a warming climate and more frequent catastrophic weather events.[4] Most of these emissions come from passenger vehicles, of which the most frequent use is driving to and from work.[5]

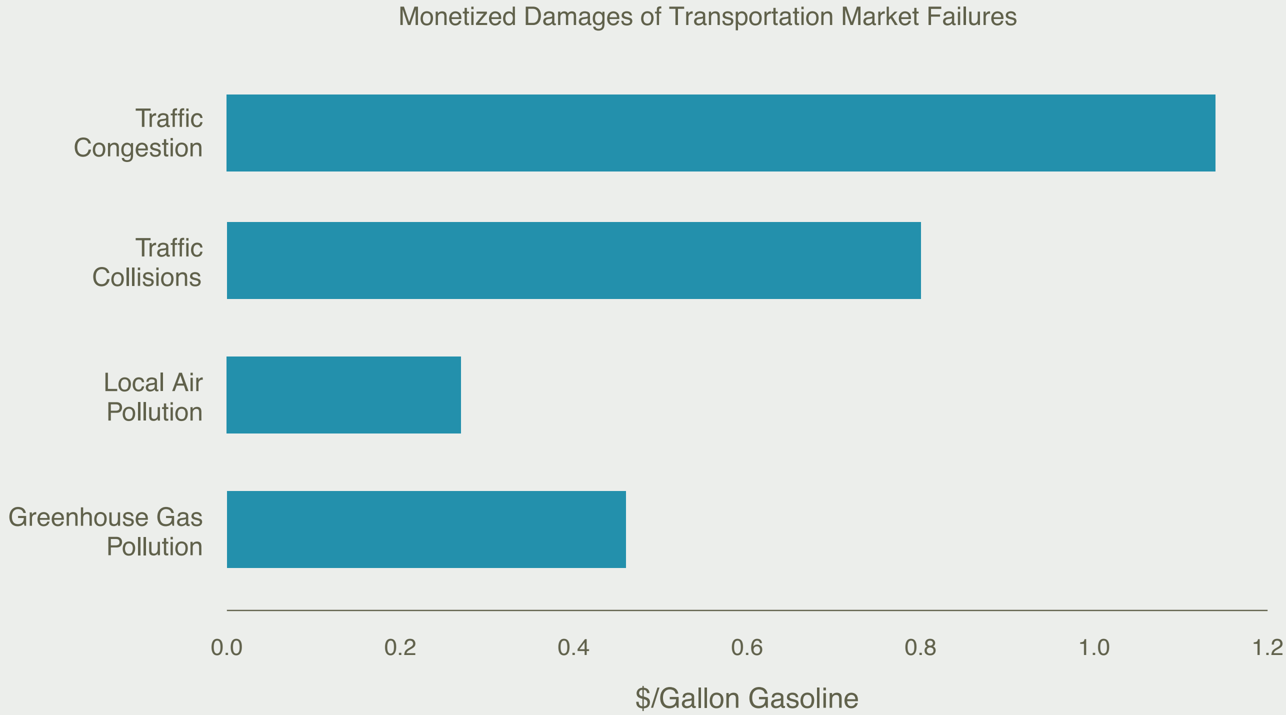
Local Air Pollution – Particulate matter, sulfur dioxide, carbon monoxide, and nitrogen oxides contribute to infant and respiratory health problems. Over the past forty years, federal and state standards have reduced some of the pollution generated from passenger vehicles, but only from newer vehicles.[6] Older vehicles still on the road generate substantial local air pollution with real health consequences – especially in densely populated urban areas.

Traffic congestion – Each year traffic congestion has become worse in nearly every city in United States.[7] As population and incomes continue to grow, so too does the demand for travel. The typical policy response to congestion – highway expansion – is unlikely to mitigate traffic congestion because it, instead, simply increases the demand for travel.[8]

Traffic Collisions – Federal safety regulations have greatly reduced the risk of harm in any single crash, however total vehicular related-deaths remain largely unchanged since the 1980s[9] as households drive more often and oversized vehicles increase the risk of harm to others.

Figure 1 illustrates the relative magnitude of major transportation market failures in terms of the marginal damages per gallon of gasoline consumed. A comprehensive policy – simultaneously addressing these market failures – is likely to be the best way to provide benefits to society that outweigh the harms.

Figure 1 – Estimated Damages of Major Transportation Market Failures per Gallon Gasoline



The damages of GHG pollution is based on the central estimate of the Social Cost of Carbon, well-understood as a lower bound. The remaining values are the median from Table 1, infra.

Economically Efficient Policies

Economically efficient policies balance the costs and benefits of mitigating the harms of each market failure. Incorporating the economic damages of every transportation activity into its price, either per-mile or per-gallon, would force individual travelers and businesses to internalize the external costs into their decisionmaking. Doing so helps better align incentives so that people move away from the costliest transportation activities without sacrificing activities that provide overall positive economic benefits to society, and therefore mitigates the harm of the market failure at the lowest possible cost. At all times, however, policymakers should bear in mind the need to avoid disproportionately burdening low-income households and should consider making simple adjustments, such as targeted exemptions or other programs, to make the policies less regressive.

Based on the latest economics literature and analysis of the damages caused by surface transportation, several principles emerge, which will be addressed more fully in this report: A per-gallon fee on gasoline of at least 50 cents is required to internalize the harm of GHG emission from gasoline combustion. Because the other externalities are more proportional to the number of miles traveled than volume of fuel used, a per-mile fee can better internalize their associated damages. A 10 cent per-mile mileage fee would internalize the average damages of the non-GHG externalities. Differentiating the mileage fee by location and time of day is also essential to mitigate the harm of congestion and air pollution. Likewise, larger mileage fees for older and heavier vehicles better address air pollution and risk of harm from traffic collisions with those vehicles.

Policies Within Reach

Accelerating the Transition to Fuel-Efficient Vehicles – Innovations in electric battery technologies provide an attractive opportunity to increase the efficiency of surface transportation. Stringent federal fuel-economy standards are another way to encourage fuel savings and decrease GHG emissions. In addition, electric vehicle subsidies can be used to increase adoption of this new technology among more price-responsive, low-income, households. Finally, a well-designed program to retire the oldest, heaviest, and pollution intensive cars and trucks can accelerate the transition towards a cleaner and safer fleet of vehicles on the road.

Reining in Fuel Consumption and Miles Traveled – Directly pricing the societal damages of each mile traveled and gallon of gasoline consumed can effectively address all of the major transportation market failures. Largely overlooked by policymakers, these policies will become more critical to mitigate traffic congestion as demand for travel grows. What is more, fuel- and mileage-based policies provide immediate benefits because they directly alter the cost to travel and consume fuel that emits harmful pollution. Increasing the federal fuel tax, limiting fuel consumption, reforming state registrations, and congestion tolls are all effective solutions to address these issues.

Direct Transportation Infrastructure Spending Towards Net-Beneficial Investments – In recent years, the federal government has spent over $70 billion on public infrastructure. These expenditures were authorized by Congress and financed by the Highway Trust Fund.[10] Ensuring that these resources go toward net-beneficial projects and take into account the external harms of transportation is essential to mitigating the future harms of transportation-related market failures. Other than explicitly supporting public transportation, policymakers should encourage the design of complete streets (which equally benefit all transit passengers regardless of whether the drive, walk, or bike) and transit-oriented development (which co-locates transit with occupations, housing, and commercial services), as well as increase the provision of electric vehicle charging infrastructure.

The Time Is Now

The ongoing coronavirus pandemic has shaken the transportation sector over the past several months. The rapid reduction in business and leisure travel, and the corresponding (though short-term) reduction in air pollution, has helped bring to light the burden of everyday transportation on human health and the environment as well as the disproportionate impact of historical transportation policies on communities of color.

Now is the time to focus on turning toward long-term policies that facilitate the reductions that are needed to avert climate change damages as well as other significant harms caused by the automobile sector. For example, now is the time for automakers to retool their factories so that they have the equipment needed to manufacture high-performance electric vehicles; policymakers designing economic stimulus programs should focus on establishing a dense national network of public electric vehicle charging stations; and companies should encourage the continuation of working-from-home, where feasible, to effectively mitigate much of the harm of surface transportation. Finally, the current low price of gasoline presents a perfect opportunity to establish policies that will rein in consumption of fossil fuels and the associated air pollutants.

This time of immense transformation is an opportunity to take actions to ensure that recovery from the COVID-19 crisis can bring the United States closer to addressing some of the market failures bedeviling the transportation sector, not away from them. If not, the country is likely to end up in an even worse situation as commuters shy away from public transportation and towards more personal vehicle travel.

I. Introduction

In 2017, the transportation sector became the largest source of greenhouse gas (GHG) emissions in the United States.[11] The damages that those emissions cause by exacerbating climate change are immense,[12] yet, climate damages represent only a fraction of all the harms caused by surface transportation – which are predominately caused by cars and trucks. Local air pollution from automobiles, time wasted in traffic, and physical harm from motor vehicle crashes all impose real costs on society that are comparable, sometimes even larger, then the costs of transportation-related GHG emissions.[13] When considering these market failures together, it is clear that the transportation sector is badly in need of reform.

Addressing any one of these market failures is an immense challenge; surface transportation creates great value, is necessary for daily life in much of the United States, is based on long-lived assets like highways, and is determined by the choices of many disparate people and entities. At the same time, policymakers are increasingly aware that mitigating the harms of these market failures is net-beneficial to society.[14]

Addressing these market failures using smart policy design can ensure that consumers and businesses continue to use transportation services that provide the most benefits while also reducing harms to society at the least-possible cost. In general, when considering alternative options, a policy designed to strategically address multiple market failures is much more likely to provide benefits that will outweigh the costs.

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This report comprehensively examines four major transportation-related market failures: greenhouse-gas emissions, local air pollutants, traffic congestion, and traffic collisions. It identifies the major determinants of each market failure, highlighting their similarities and differences. It also discusses how damages from these market failures can be quantified and indicates relevant literature with estimates. Understanding what contributes to these market failures, and how they are related, is paramount for efficient and effective policy design.

Motivated by economic theory, the report outlines the economically optimal policies to address these market failures: the combination of a gasoline tax starting at approximately 50 cents per gallon to address GHG emissions and a mileage tax in the form of vehicle registration or a toll of roughly 10 cents per mile to address the remaining major market failures. Differentiating the mileage tax by vehicle size, vehicle vintage, location, and time-of-day would improve social welfare.

Of course, this report recognizes that the economically optimal policy is not always feasible because of political or legal constraints. In addition, it may not be immediately possible to implement the economically optimal policy because of potentially competing priorities such as equity or even more rapid decarbonization. Focusing on practical policy recommendations based on economic and policy research, the report outlines three mutually reinforcing and necessary avenues through which government intervention can nonetheless address these major market failures. These avenues can be generalized as “vehicle-based policies,” “fuel & mileage policies,” and “infrastructure policies.”

Finally, this report highlights the socio-economic dimension of transportation's burden. Deliberately discriminatory land-use and transportation policies have led to a deeply inequitable society, where people of color are more likely to live in neighborhoods that are closer to highways or have less access to reliable public transportation, among many other problems.[15] As a result, transportation's market failures disproportionately harm low-income and historically disadvantaged groups, and ultimately contribute to unequal outcomes. To help policymakers mitigate the harm done to already disadvantaged groups, this report identifies both procedural and substantive policy recommendations.

What Are "Market Failures"?

In a perfectly competitive market, individual self-interest will direct society's resources towards the pursuits that create the most value.[16] In practice however, a perfectly competitive market is hard to come by. Many markets, including the market for transportation, are marred by what economists call "market failures."[17] When there are market failures, prices no longer reflect the social marginal cost, and the resulting allocation of resources in the economy is no longer the one that makes everyone best off. Examples include the existence of market power, trade frictions, incomplete information, or economic costs or benefits that are not transacted in a market ("unpriced externalities"). In those circumstances, regulatory intervention to address the market failure can increase society's welfare.[18]

II. Major Market Failures in Surface Transportation

This report first documents four externalities that affect the market for transportation: GHG emissions, local air pollutants, traffic congestion, and traffic collisions. For each, the major sources, determinants, and methods of quantification are detailed. After summarizing academic and regulatory analysis that has quantified the magnitude each externality on a "per-mile" or "per-gallon" basis, this report briefly discusses other related transportation market failures that policymakers should also consider when designing transportation policy.

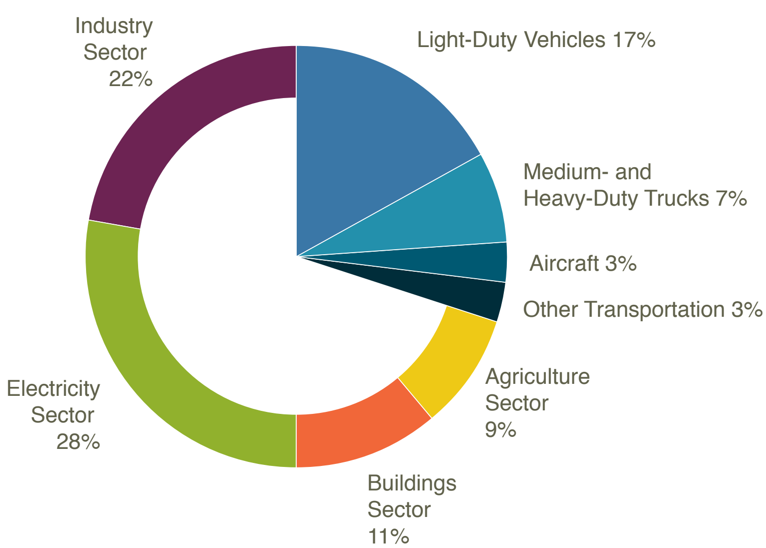
Externalities in Surface Transportation

Greenhouse-Gas Emissions

Combustion of transportation fuels like gasoline and diesel generates GHG emissions that contribute to global climate change.[19] The potential damages from anthropogenic climate change – increased temperature, property damage, reduced productivity, and induced mortality – are immense.[20] However, individual consumers and businesses have limited, to no, economic incentive to consider the magnitude of these damages when deciding when and how much to travel.[21] Travelers consider other costs, like the monetary cost of fuel or the time cost of travel, but do not pay for the associated damages of more GHG emissions. As a result, a traveler's preferred quantity of fossil-fuel consumption imposes a cost on society – of increased fuel use and GHG pollution – which can exceed the benefit the traveler derives from the use of that fuel.

Because the climate change related damages of GHG emissions are external to the traveler's consideration and impose a real cost on third parties, economists call these emissions a "negative externality."[22] An externality is one of the most basic market failures. Correcting for the externality, by forcing consumers to consider the harms of GHG emissions, will reduce the combustion of transportation fuels and increase social welfare.

Figure 2 – Sources of GHG Emissions in the United States, 2017



A pie chart characterizing the source of GHG emissions in the United States. Other Transportation includes rail (0.6%), ships and boats (0.9%), and buses, motorcycles, pipelines, and other chemicals (collectively 1.2%). See US EPA, Fast Facts U.S. Transportation Sector GHG Emissions 1990-2017, EPA-420-F-19-047, June 2019.

Overall, the transportation sector is responsible for 30% of all domestic GHG in the United States, of which carbon dioxide (CO_2) emissions are the main source.[23] Light-duty vehicles, including passenger vehicles and light-duty trucks, are the primary source – accounting for nearly 60% of all transportation GHG.[24] Medium- and heavy-duty trucks, including freight, account for the majority of the remaining emissions. Together, surface transportation in the form of on-the-road vehicles account for over four-fifths of all GHG emissions from transportation.

The difference between these light-duty vehicles and medium- or heavy-duty trucks highlights one important determinant of transportation GHG emission and nearly every other transportation market failure: total vehicle-miles traveled (VMT). This value measures the total number of miles traveled by a vehicle in a certain time period. For example, in 2017, the entire fleet of light-duty passenger vehicles was responsible for nearly 3 trillion VMT; more than nine-times the total VMT of all medium- and heavy-duty trucks.[25] With such a difference in total VMT, it should be of little surprise that passenger vehicles are the number one source of all transportation GHG emissions.

Although VMT is important, it is only one feature of transportation use that contributes to GHG emissions. There are three factors that can increase, or decrease, total surface transportation GHG emissions. Understanding each one is important when choosing amongst policy alternatives, as it may be easier or more cost-effective to adjust along some of these fronts than others. Specifically, the three factors are:[26]

A. **The demand for travel**, measured in VMT. As travelers choose to take more trips, or travel further distances, more transportation fuel is needed. For transportation fuels that generate GHG emissions, the amount of emissions will increase with VMT. The demand for travel is mainly determined by the price of fuels, household income and preferences, as well as expected travel time and the quality of public infrastructure.[27]

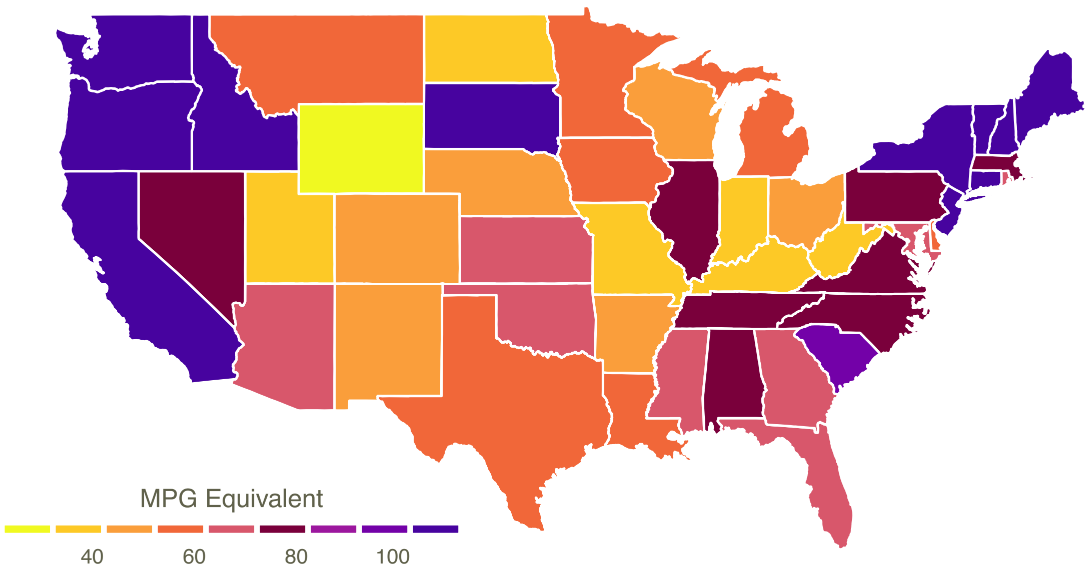
B. **The efficiency of travel**, measured in the amount of energy required to move a person one mile. The efficiency of travel is determined by the fuel economy and the passenger capacity of the associated transit mode. As fuel economy increases, less fuel is required per mile traveled, and so GHG emissions decrease. Electric vehicles (EVs) are a promising way to increase vehicle efficiency, as they can travel three or four times as far as gasoline vehicles with the same amount of energy.[28] Otherwise, increasing the number of people traveling in a vehicle through public transit or carpooling can also increase the efficiency of travel.[29]

Electric vehicles (EVs) are a promising way to increase vehicle efficiency, as they can travel three or four times as far as gasoline vehicles with the same amount of energy.

C. **The carbon intensity of the fuel**, measured in tons of CO_2 equivalents per unit of energy. Some fuels are more carbon intensive than others. The primary transportation fuel, accounting for 66% of GHG emissions, is motor gasoline, which releases 19.6 pounds of CO_2 per gallon of fuel combusted regardless of how it is combusted.[30] Distillate fuel, including diesel, generates a majority of the residual share. Other fuels, such as biofuels, natural gas, hydrogen, and electricity are generally less carbon intensive then conventional gasoline and diesel. Biofuels and electricity are easier substitutes for motor gasoline; however, they are not always guaranteed to be less carbon intensive, especially once the GHG emissions associated with their production are accounted for.[31] As the electricity grid becomes powered by more renewable energy, and less coal, the carbon emissions associated with EVs decline.[32]

The first factor (A) represents quantity of GHG emissions determined by total demand for travel. Reducing GHG emissions this way is difficult because it requires people to drive less often, which means elimination of trips (e.g., working from home) or finding creative ways to make trips shorter. The second and third factors (B and C) contribute to the carbon intensity per mile traveled. GHG reductions through this dimension allow consumers to enjoy the same level of travel, but with less GHG emission overall. This can be accomplished by improving the fuel-efficiency of passenger vehicles, carpooling or reallocating trips to more environmentally friendly modes like public transportation. Unfortunately, under-provision of reliable public transportation or similar infrastructure can limit a traveler's ability to pursue passenger-vehicle alternatives as a means to reduce GHG emissions.

Figure 3 – Carbon-Efficiency of EVs Based on State Electricity Production



A map showing the carbon-efficiency of EVs – the miles that can be traveled by EVs while generating the same carbon dioxide emissions as a gallon of gasoline – based on state electricity production. Calculations are based on public data from the Energy Information Agency on the carbon intensity of state-level electricity production (in tons of carbon dioxide per kilowatt-hour of electricity in 2018), and a constant average electric vehicle energy efficiency of 0.32 kilowatt-hour per mile.

Looking towards the future, technology improvements such an increased fuel economy and wider adoption of electric vehicles have immense potential to decrease transportation GHG, especially if supported by policymakers and regulators. These reductions are made possible by reducing the carbon intensity of each mile traveled. Figure 3 highlights this fact, showing the miles that can be traveled by an electric vehicle while generating the same amount of carbon dioxide pollution as in a gallon of gasoline – as determined by mix of fuels used to produce electricity in each state. However, as the economy grows, it is possible the ever-growing demand for miles traveled will undo the reduction in GHG emission per mile traveled.[33] For this reason, reducing GHG emissions through demand reduction should not be ignored.

Quantifying the harm to society of transportation GHG emissions is relatively straightforward. All that is required is a monetized value of the harm to society for each additional ton of GHG emissions. At this moment the **Social Cost of Carbon** is the best available tool to accomplish this exactly. The federal Interagency Working Group's (IWG) 2016 estimates of the Social Cost of Carbon included a central value of $52.[34] Although there is a broad consensus that the IWG's Social Cost of Carbon central estimate is a valid and useful metric, it currently omits many important costs traceable to GHG emissions such as extreme temperatures and changes in precipitation patterns.[35] For this reason, the IWG's range of estimates are rightly understood as a lower bound and the true costs of GHG emissions are likely to exceed $52 per metric ton.

Because the carbon content of fuels is relatively constant, it is possible to tie each unit of fuel to its associated economic damages.[36] For example, each gallon of motor gasoline emits 19.6 pounds of carbon dioxide regardless of how it is combusted (aside from the additional GHG emissions upstream, which can vary).[37] With 2200 pounds per metric ton, and 100 cents per dollar, the economic damages of a gallon of gasoline in cents is roughly equivalent to the social cost of a ton of carbon dioxide in dollars. Thus, the cost to society of each additional gallon of gasoline is roughly 50 cents per gallon using the central estimate for the Social Cost of Carbon.

Key Term: The Social Cost of Carbon

The Social Cost of Carbon measures and monetizes the external damage that results from emission of a ton of CO_2 into the atmosphere. Because CO_2 is a global pollutant, a ton emitted causes the same amount of damage regardless of where the emission occurs. As a result, a single price, applicable regardless of location, is appropriate for monetizing damages. **The Interagency Working Group's (IWG) 2016 Social Cost of Carbon estimate is the best currently available estimate for the external cost of CO_2 emissions.**[38] The IWG's methodology has been repeatedly endorsed by reviewers. For example, in 2014, the U.S. Government Accountability Office concluded that IWG had followed a "consensus-based" approach, relied on peer-reviewed academic literature, disclosed relevant limitations, and adequately planned to incorporate new information through public comments and updated research.[39] But it is a lower bound estimate of the damages from these emissions.[40]

Local Air Pollution

The combustion of transportation fuels creates other pollutants that contribute to poor local air quality including nitrogen oxides (NO_x), particulate matter (PM), volatile organic compounds (VOCs), sulfur dioxide (SO_2), and carbon monoxide (CO).[41] Collectively, these Transportation Related Air Pollutants are responsible for, among other things, increased infant mortality, adolescent asthma, low birthweights, lower economic productivity, and poor student achievement.[42]

These pollutants are paradigmatic negative externalities. When travelers decide which car to buy, or how much they drive, they do not fully consider how associated Transportation Related Air Pollutants will harm others by decreasing their quality of life and damaging their health.

Like GHG emissions, local air pollution is determined by the demand for travel and the emissions per mile traveled. The first determinant is simple, more miles traveled means more local air pollutants so long as the vehicle emits some pollutants. Unlike GHG emissions, Transportation Related Air Pollutants are not constant per unit of fuel. Instead, the quantity of Transportation Related Air Pollutants generated from surface transportation is best characterized per mile in part because Federal standards for the emission of these pollutants from new vehicles are set per-mile.[43]

Some fuel types emit more Transportation Related Air Pollutants than others. For example, motor gasoline generates less SO_2 and PM than diesel,[44] and EVs only generate air pollutants in-so-far as their use of electricity is from pollution intensive electricity generators like coal power plants. Even within the same general fuel type, the Transportation Related Air Pollutants emitted per unit of fuel can vary. For example, motor gasoline consists of a few different "blends," some of which emit less local air pollutants than others.[45]

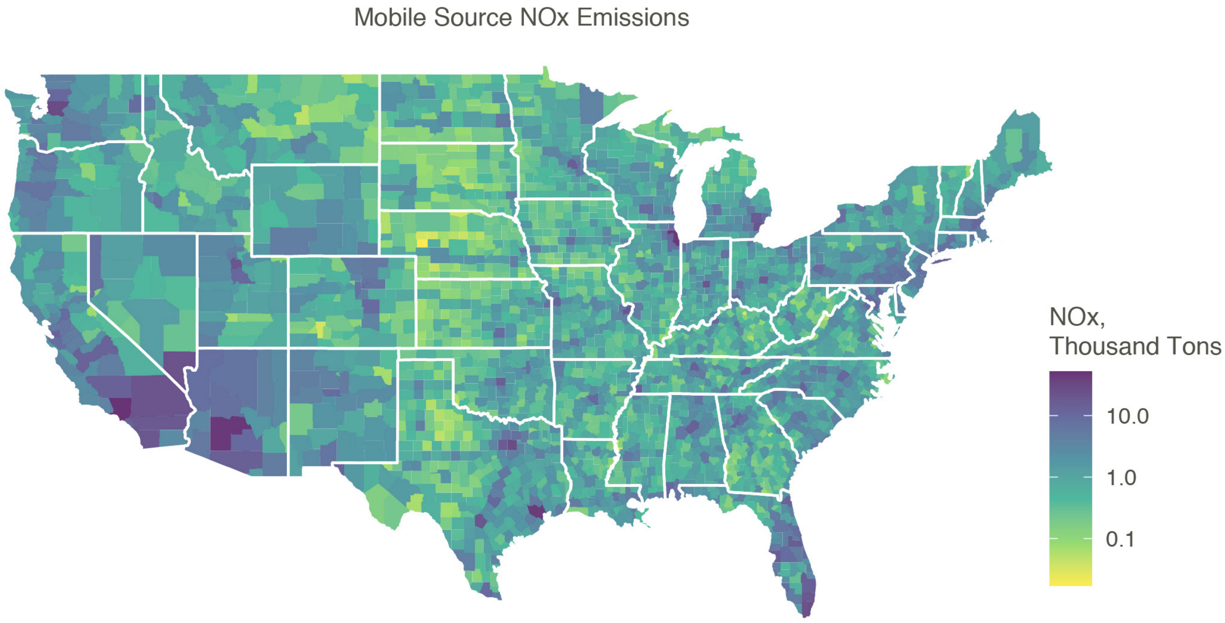
Just as important as the fuel used are factors such as vehicle technology and age. Certain technologies, like catalytic converters, play an important role in decreasing emissions per unit of fuel. Over time, these types of technologies have improved significantly thanks to federal standards.[46] As an implication of this, older vehicles generate a lot more Transportation Related Air Pollutants than newer ones using the same amount of fuel. Heavy-duty trucks, the largest source of PM among transportation sources,[47] illustrate this fact well: replacing trucks manufactured prior to 2000 with newer models can reduce 92% of truck-related PM pollution.[48]

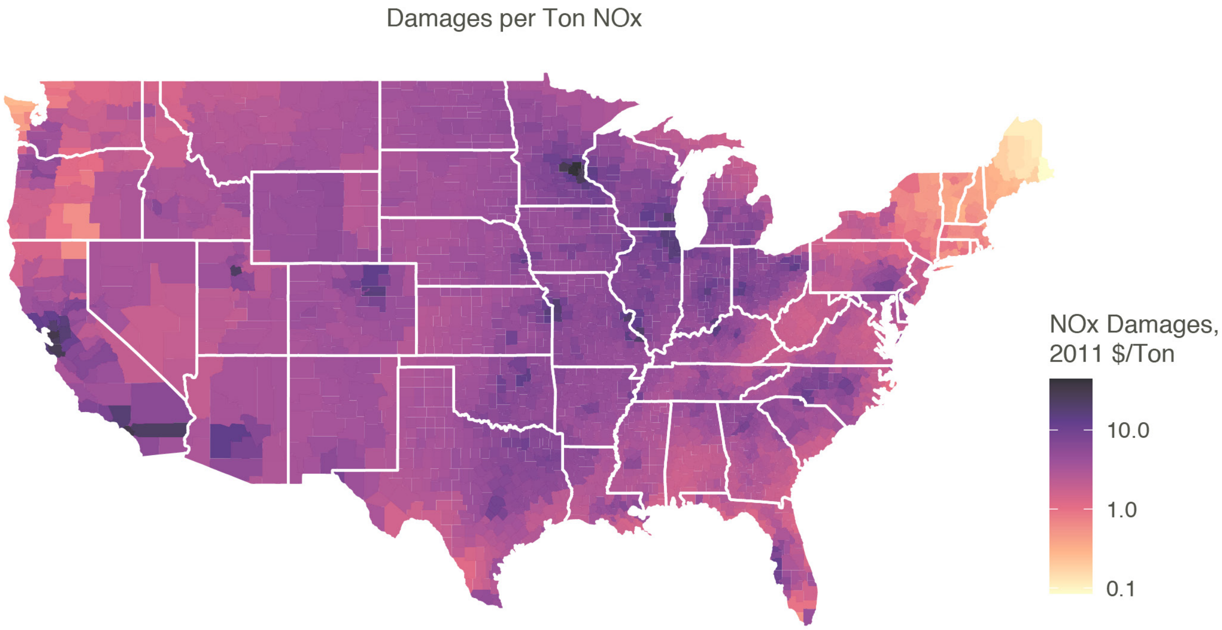
Replacing trucks manufactured prior to 2000 with newer models can reduce 92% of truck-related PM pollution.

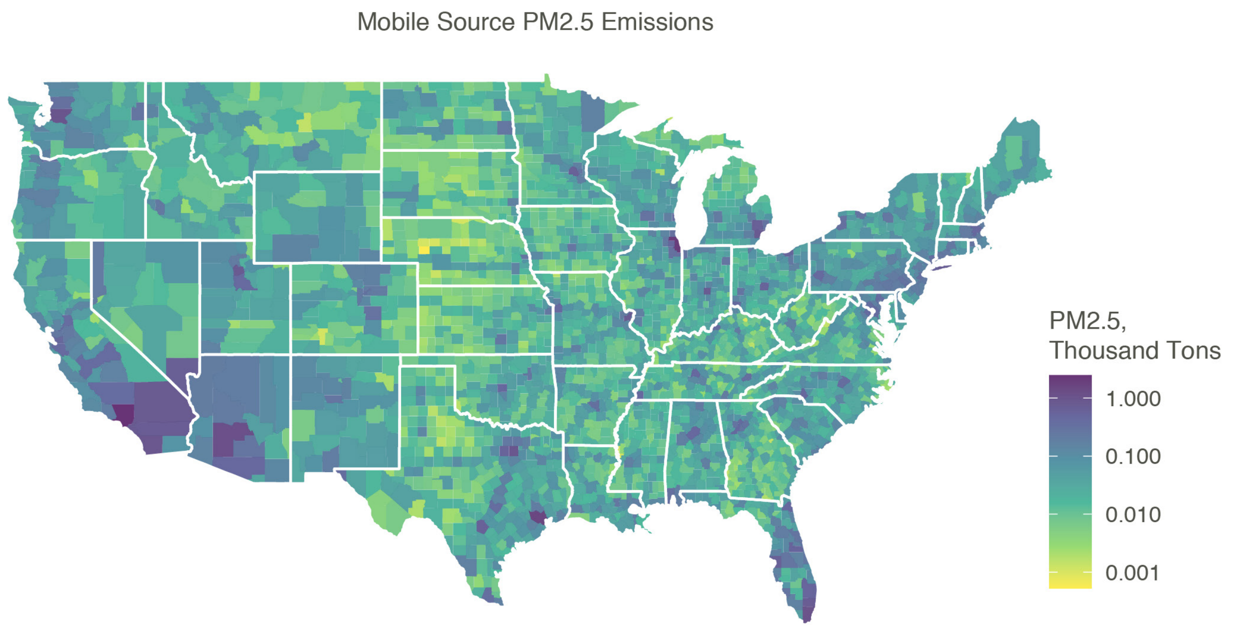
As the name suggests, the damages caused by local air pollutants depend on the location (and time) that the pollution settles near people and industry.[49] Damages per unit of pollution increase in proportion to the number of people exposed and their underlying health status. For this reason, local air pollutants can be a serious problem in the urban areas with high population density, where more than 80% of people live in the United States.[50]

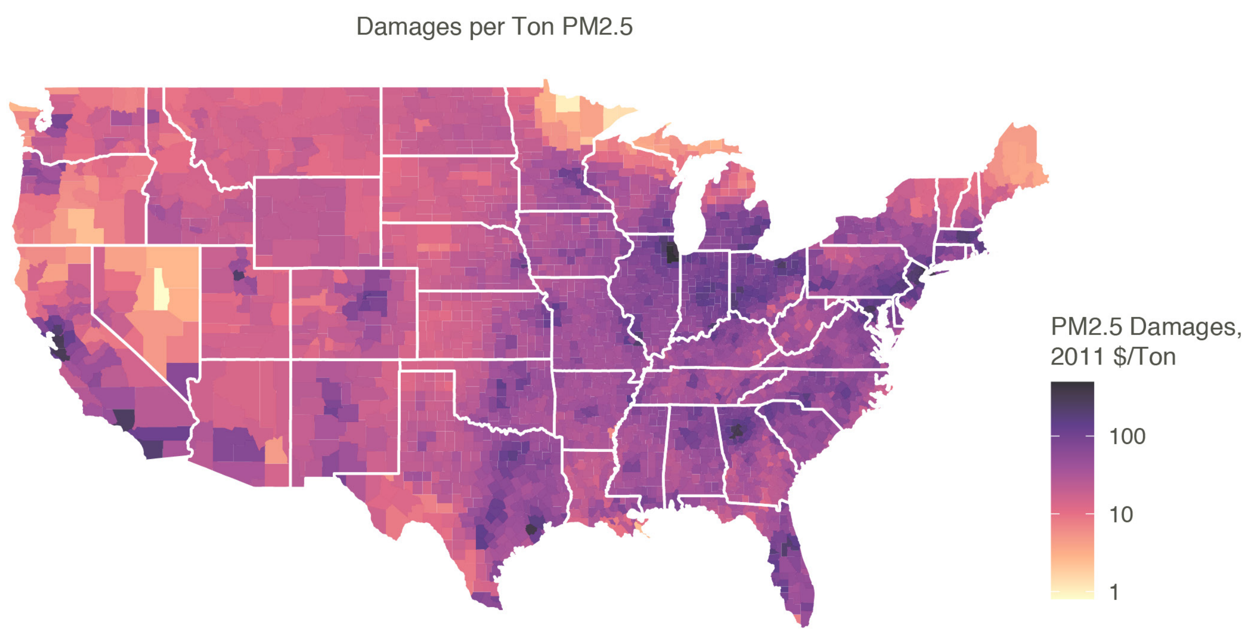
Unlike with GHGs, there is no single value that can be used to calculate the economic and public health damages that are caused by vehicle emissions, regardless of where they are generated. However, several tools exist to model and estimate damages in particular geographic areas.[51] For example, the AP2 model provides county-specific monetized damages for VOCs, NO_x, and PM.[52] Comparing the geographic distributions of local air pollution and the monetized harms per unit of pollution, as done in Figure 4, shows most pollution is happening in urban areas, where it creates the most damage. This suggests localized policies might be best to mitigate the associated harm.

Figure 4 – County-Level Air Pollution and Economic Damages









Maps showing local air pollution (tons of particulate matter and nitrogen oxides) from mobile sources according to the 2014 EPA National Emissions Inventory, and the corresponding economic damages per ton of pollution by county according to the AP2 model detailed at https://public.tepper.cmu.edu/nmuller/APModel.aspx.

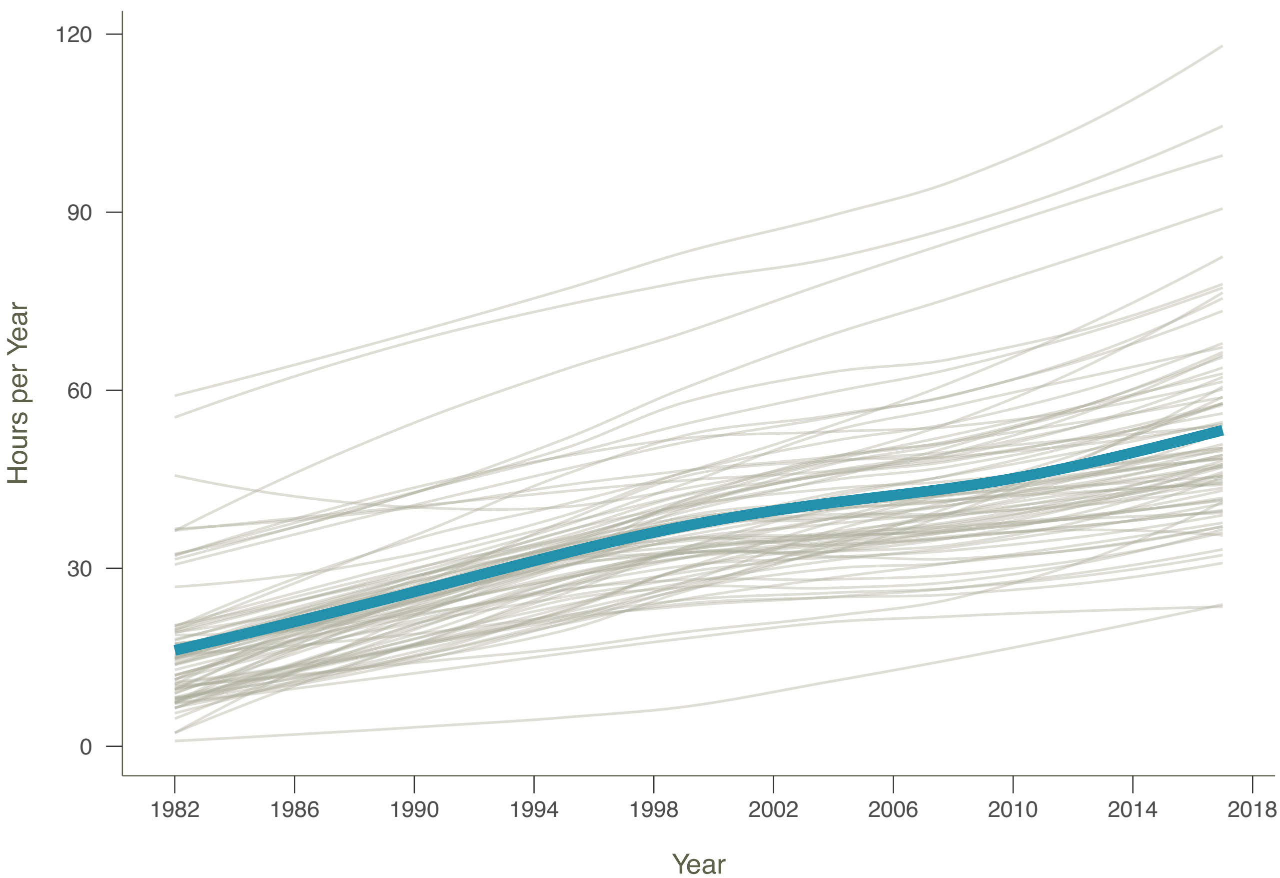
Traffic Congestion

When the number of cars on the road exceeds a proportion of the road's capacity, each additional car makes all other travelers slow down and spend more time getting to their destination (while also using more fuel and generating more air pollution). The primary cost of traffic congestion is the increased travel time of others, and is another form of a negative externality.[53] Even if decisionmakers consider their own time spent traveling, they likely have little-to-no incentive to consider if, and how much, they will increase the travel time of others. As a result, total vehicles on the road are higher than what is optimal from society's perspective.

Like all market failures discussed so far, the harm of congestion increases with total VMT. As the demand for travel increases, more people and businesses are simultaneously contributing to and the subject of more congestion. To illustrate this, Figure 5 shows the average delay of commuters, in hours-per-year, for over 100 medium, large, and very large metropolitan areas in the United States since 1982. During the same time period, national VMT more than doubled.[54]

Figure 5 – Growing Traffic Delay in Metropolitan Areas Since 1982

Hours Delayed by Traffic for the Average Driver in U.S. Urban Areas



Average hours stuck in traffic per year for medium and large metropolitan areas since 1982. The national average is in green. Data are from Texas A&M University transportation center.

The harm of traffic congestion for each additional vehicle miles travelled depends on two values. The first, referred to the "marginal external cost of traffic congestion," measures how one more car or truck on the road reduces everyone else's travel time.[55] This value varies by time of day and place; it is much higher during periods of rush-hour traffic in downtown areas.

The second determinant of traffic congestion harm is the economic value of the time wasted in traffic, aptly called the value of time. An analysis of 56 studies in 14 nations led to a general rule commonly used today: the value of time is roughly half the median wage.[56] Because of the additional mental unease of waiting around in traffic, it is common to use a multiplier for time spent delayed.[57] Recent guidance by the Department of Transportation is consistent with this general rule, suggesting 50% of the median wage for leisure travel and 100% of the wage for business travel, although it stops short of using a multiplier for traffic delay.[58]

Because incomes are typically higher in urban areas, where there is more congestion, the value of the harm to society of traffic is higher there. For example, in New York, Los Angeles, and Chicago, people spend over 100 hours per year in traffic. Even a modest value of time ($15/hour) implies a huge cost of traffic congestion per person on average (>$1,500). With millions of commuters each day, the cost of traffic congestion to each one of these cities is in the billions of dollars annually.

Traffic Collisions

Motor vehicle crashes have been responsible for 30 to 50 thousand fatalities per year since 1980.[59] Even though the total number of annual fatalities has declined slightly over that period, primarily thanks to regulatory requirements to improve vehicle safety, traffic collisions continue to impose substantial societal costs.

Motor vehicle crashes are an externality because a person may not fully consider how their actions can affect the risk-of-harm to others, even if they consider the risk-of-harm to themselves.[60] As all the other market failures discussed so far, this is an externality and government action can produce substantial societal net benefits by reducing the risk of vehicle collisions. Liability laws, which require drivers to insure against some of the harm of such crashes, force consumers to consider these risks to some extent when making decisions.[61] The degree to which these laws force consumers to perfectly internalize risk of harm to others depends in part on state law and how the insurance policies are designed.[62]

These crashes cause substantial harms largely in the form of loss of life and decreased quality of life through fatal and non-fatal injuries, but also from property damage, induced traffic congestion, increased travel time, and medical costs.[63] One estimate suggests, for example, that total comprehensive damages from traffic collisions in the United States exceeded $800 billion in 2010.[64]

Collisions are more likely to happen when there are more cars on the road, and so, the magnitude of the market failure increases with total VMT. Beyond that, speed, weight and other technical vehicle features (like air bags, seat belts, and crumple space) are important determinants of the damages from a single crash. For example, one study found a 10 mph increase in the speed limit leads to more crashes and more fatal crashes.[65] And another found that being hit by a heavier vehicle "generates a 40–50% increase in fatality risk" to the occupants in the vehicle being hit.[66]

Quantifying the harm of traffic collisions requires a connection between VMT, vehicle weight, and speed to mortality, non-fatal injuries, and other economic damages. Many tools exist to place an economic value on the resulting loss of life, non-fatal injuries, property damage and medical costs.[67] A well-accepted tool for monetizing mortality is the value of a statistical life (VSL), which measures the amount of money an individual is willing to accept for a small increase in the probability of a fatal injury.[68] The Environmental Protection Agency currently recommends using a VSL of $9.7 million in 2020 dollars,[69] while the Department of Transportation recommends a VSL of $10.4 million. These numbers suggest that 30 thousand fatalities per year corresponds to roughly $300 billion in damages from fatalities alone.

Table 1: Magnitude of Major Market Failures

Table 1 provides estimates for the external damages associated with the four major market failures in terms of per-gallon, or per-mile, costs. It is important to emphasize that these estimates are averages and sometimes specific to the underlying study. The actual damages from these market failures will vary by time-of-day, location, and vehicle features (such as age and weight).

Market Failure	Damage Estimate		
	Source	Per Gallon	Per Mile
Carbon Emissions	2020 SCC, 2.5% discount rate	$0.15	$0.02*
	2020 SCC, 3% discount rate	$0.46	$0.01*
	2020 SCC, 5% discount rate	$0.68	$0.03*
	2020 SCC, High Impact, 2.5% discount rate	$1.35	$0.06*
Local Air Pollution	Kenneth Small and Camilla Kazimi, 1995.	$0.66*	$0.03
	US DOT, 2000.	$0.49*	$0.02
	IMF, 2015.	$0.11	$0.01*
	Chris Knittel and Ryan Sandler, 2018.	$0.27	$0.01*
	Cody Nehiba, 2020.	$0.03	$0.00*
Traffic Congestion	US DOT, 2000	$1.54*	$0.07
	IMF, 2015.	$1.14	$0.05*
	Cody Nehiba, 2020.	$0.60	$0.03*
Traffic Collisions	US DOT, 2000	$0.36*	$0.02
	Ian Parry, 2004	$1.31*	$0.06
	IMF, 2015.	$0.49	$0.02*
	Michael Anderson and Max Auffhammer, 2014.	$1.10	$0.05*

*Notes: All estimates are inflated to 2019 dollars. These estimates are generally provided in either per-mile or per-gallon estimates. Therefore, in order to report both estimates here, this chart provides derived estimates, converted from per-mile to a per-gallon measure (or vice versa) assuming 22 miles per gallon fuel efficiency. The derived estimates are denoted by an *.*

Sources:
SCC stands for the IWG Social Cost of Carbon. *See* Revesz et al., *supra* note 34, at 655; Kenneth A. Small & Camilla Kazimi, *On the Costs of Air Pollution From Motor Vehicles*, 29 J. Transport Econ. Policy 32 (1995); U.S. Dep't of Transp., Addendum to the 1997 Federal Highway Cost Allocation Study Final Report U.S. Dep't of Transp. Fed. Highway Admin. (May 2000), https://www.fhwa.dot.gov/policy/hcas/addendum.cfm; Int'l Monetary Fund, Energy Subsidies Template (2015), www.imf.org/external/np/fad/subsidies/data/subsidiestemplate.xlsx.; Christopher Knittel & Ryan Sandler, *The Welfare Impact of Second-Best Uniform-Pigouvian Taxation: Evidence from Transportation*, 10 Am. Econ. J. Econ. Policy 211, 230 (2018); Ian W.H. Parry & Kenneth A. Small, *Does Britain or the United States Have the Right Gasoline Tax?*, 95 Am. Econ. Rev. 1276 (2005); Michael L. Anderson & Maximilian Auffhammer, *Pounds That Kill: The External Costs of Vehicle Weight*, 81 Rev. Econ. Studies 535 (2014); Ian W.H. Parry, *Comparing Alternative Policies to Reduce Traffic Accidents*, 56 J. Urb. Econ. 346 (2004); Cody Nehiba, *Correcting Heterogeneous Externalities: Evidence from Local Fuel Taxes* (U. of Cal., Irvine, Working Paper, 2020), http://www.usaee.org/usaee2018/submissions/Presentations/Nehiba_DC18.pdf.

Other Market Failures

Externalities do not nearly cover all of the ways in which under-regulated surface transportation can cause net societal harm. Four other significant issues with the surface transportation sector, which are caused by either another market failure or a mix of other market failures, could benefit from government intervention.

Incomplete Valuation of Fuel Savings

When purchasing a new or used vehicle, there are several "market failures" that explain why consumers might not choose a more fuel-efficient vehicle, even if that choice will save them money over the lifetime of the vehicle compared to otherwise identical vehicles.[70] Broadly, this incongruity between what is privately rational and the consumer's actual decision is referred to as the "energy-efficiency gap."[71] Explanations for this energy-efficiency gap include the costs of acquiring information on fuel economy,[72] consumer aversion to losses today with uncertain future benefits,[73] present bias in their internal accounting,[74] among other explanations.[75] When these market failures exist, an intervention directing consumers towards more fuel efficient vehicles, through labeling or other means, can save consumers money and reduce GHG emissions.

Under-Provision of Fuel-Efficient Vehicles

There are two reasons firms might not have the right incentive to produce fuel-efficient vehicles. First, if there is any market power, automakers can price-discriminate and under-provide fuel economy to the consumers that might not value it fully (for reasons outlined above).[76] Faced with limited competition, auto manufacturers "put more effort into attributes that consumers have regularly sought in the past, such as size and power, than into fuel and time savings with uncertain future returns" and offer "a limited number of vehicle attributes among which consumers can choose."[77] Second, there is a free-riding concern regarding research and development for new fuel-efficient technologies. Because competitors can benefit from another automakers' innovation, each automaker will invest in less research and development than what is socially optimal.[78] As a result, requiring automakers to improve fuel economy can increase welfare.

Learning-By-Doing and Diffusion of Network Technologies

The net benefits of some technologies, like EVs, increase in proportion to the number of units produced and in active use.[79] This could be because the costs decrease as more units are produced and manufacturers learn how to reduce the production cost, a phenomenon called "economies-of-scale" or "learning-by-doing." Or, it could be that the benefits increase as a network of other consumers forms. For example, as EVs become more prevalent, so too does charging infrastructure, which will in turn increase the value of EVs.[80] This is a market failure, as each individual consumer or producer does not consider the benefit they provide to others in reducing the future cost, or increasing their future benefit. As a result, technology-forcing regulation that spurs investment in EVs and related charging infrastructure can make society better off.

Highway Maintenance

The provision of a public good, like safe and reliable interstate highways, suffers from a free-rider problem.[81] When anyone can access this service, there is no incentive for individuals to pay their fair share towards its maintenance. As a result, these projects will be under-funded. This has long been recognized as a problem in transportation in the United States. To address this issue for highways Congress has established the Highway Trust Fund financed by a federal excise tax on gasoline and diesel, as well as excise taxes on other motor-vehicle related goods such as tires or new heavy-duty vehicles. In recent years, however, this fund has been insufficient to support the surface transportation programs authorized by Congress.[82]

III. Economically Optimal Policies to Address the Major Market Failures

The following are the economically optimal policies for addressing the market failures outlined above.[83] They are economically optimal in the sense that they match the marginal damages of each market failure with the marginal benefits of each transportation choice. Political and legal constraints may make it difficult to implement these policies. And other policies may better meet other non-efficiency criteria such as how easy they are to administer, how quickly they can be implemented, how they will affect different demographics. Nonetheless, it is useful to understand the economically optimal policies in order to evaluate other alternatives.

Equity in Optimal Policy Design

Transportation is an important component of everyday life for most households in the United States regardless of household income. As a result, policies designed to reduce fuel consumption or miles traveled by increasing their cost have the potential to disproportionately burden low-income households. This is especially true in poor rural areas. Although not traditionally an explicit goal of regulatory rulemaking, it is important for these factors to be considered.[84] Simple modifications to the following policies – such as narrowly targeted exemptions, reimbursements, or other compensating programs (like free public transit) using tax revenues – can make the policies less regressive, possibly even progressive, while simultaneously decreasing the harms of transportation market failures.[85]

Pricing Carbon Content of Fuels Can be the Economically Optimal Solution to Surface Transportation GHG emissions

An economy-wide price on GHG emissions equal to their social costs is the first-best solution to address the damages of GHG emissions. This policy would force everyone to consider the cost of GHG emission when making their decisions. So long as demand responds to prices, carbon emissions will decrease. Absent an economy-wide carbon price, a fuel-specific price equal to the social cost of transportation fuels can be an economically optimal way to deal with transportation GHG emissions to the extent that consumers respond to fuel prices.[86] This ensures transportation choices account for the damages of GHG emissions. A specific price – per gallon – is appropriate because the carbon content of most liquid fuels is relatively constant per volumetric unit.[87]

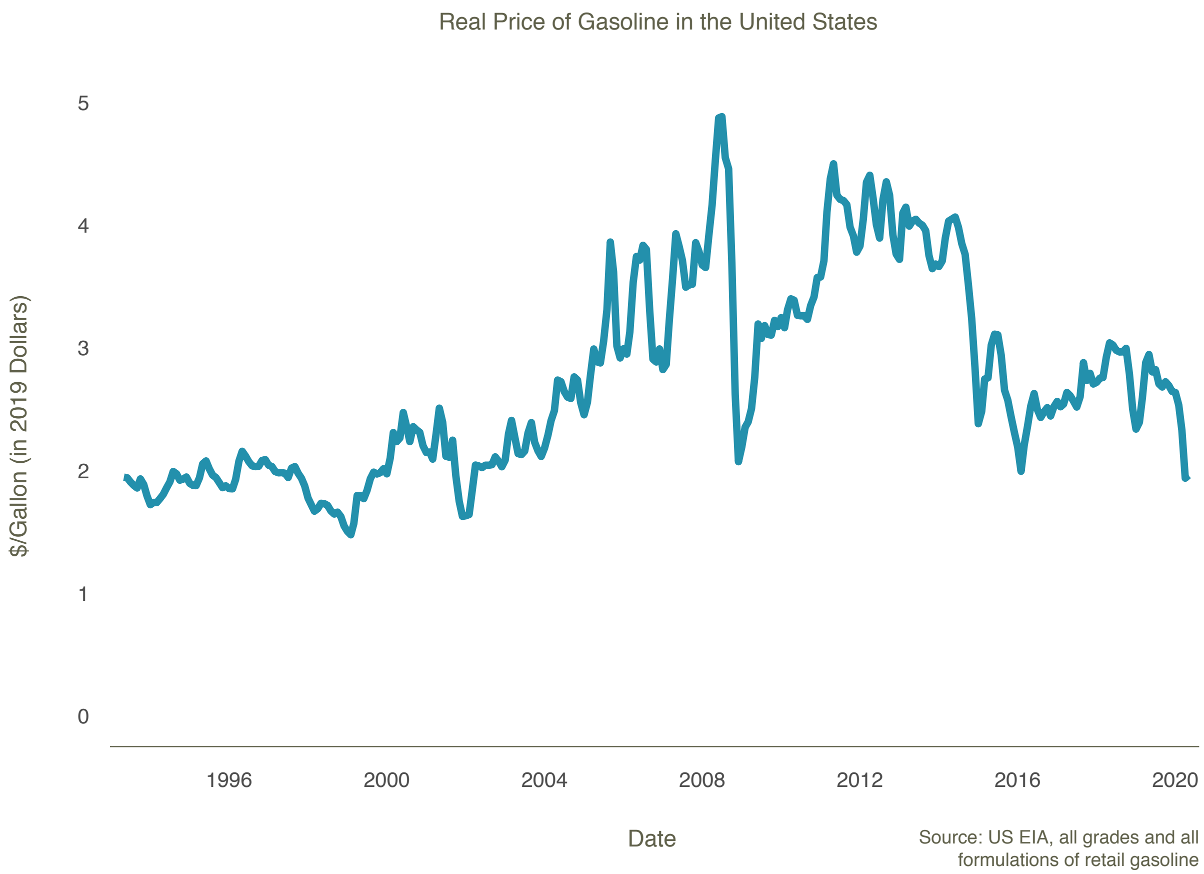
A fuel-specific carbon price in proportion to its climate damages accomplishes a few things. First, as GHG intensive fuels become more expensive, consumers will demand less of them. In principle, the price increase will discourage activities only if they are not worth that additional cost of using those fuels. For example, consumers will be discouraged from idling and driving when not necessary. This mechanism targets the GHG emissions society values the least, and so, drives down GHG emissions at the lowest possible cost. This cost-minimizing feature is one of the most attractive features of a carbon price.

Second, a fuel-specific carbon price makes fuel-efficient transportation choices, like public transportation and carpooling, more attractive as they become less costly compared to GHG-intensive alternatives. This way, when consumers and businesses are making decisions, they place value on each alternative according to the true cost to society. In the longer-term, this would induce a shift towards more fuel-efficient vehicle purchases and an expedited scrappage of fuel-inefficient vehicles.[88]

For gasoline, as an illustration using the IWG's current central estimate of the Social Cost of Carbon, a fee of at least 50 cents per could be used to help internalize gasoline's climate damages.[89]

The resulting change in fuel consumption depends on how consumers respond to the fuel price – what economists call the price elasticity of demand for fuel. As an example, using that SCC-based number, a price elasticity of -0.1 suggests a 50-cent increase in the price of each gallon of gasoline (in the form of a 50-cent fee per gallon) would decrease gasoline consumption by 2 to 2.5%.[90] Estimates for the price elasticity of demand, using transitory changes in price, are around this value.[91] Recent research suggests that consumers reduce their fuel consumption much more in response to a permanent price change, like a tax increase, than transitory ones – perhaps three to four times as much per unit of price change.[92] This suggests the same 50-cent increase in the price of fuels could decrease fuel consumption by 6 to 10%.[93] A 50-cent increase in the price of gasoline is small relative to the historical volatility of gasoline prices over the past thirty years, shown in Figure 6, even though it has the potential to reduce GHG emissions by 6 to 10%.

Figure 6 – Historical Volatility of Gasoline Prices in the United States



The external damages of GHG emissions from the combustion of gasoline, 50 cents per gallon, is 10% to 25% of the price cost of gasoline over the past three decades.

One distinct advantage of a carbon price over alternative policies is the sizeable co-benefits in the form of reduced traffic collisions, local air pollution, and traffic congestion. This is because a carbon price will reduce total VMT, which is proportional to the damages of these market failures. This is especially true for older and heavier fuel-inefficient vehicles that disproportionately emit more local air pollutants and contribute to traffic fatalities.

Pricing Mileage Can Be the Economically Optimal Solution to Other Externalities

Traffic congestion, crashes, and local air pollution are almost directly proportional to VMT. So, a fee on VMT that equals the sum of the damage from each uninternalized externality caused by an additional mile traveled would internalize those damages and could lead travelers to make driving decisions that improve social welfare. This would be economically efficient, to the extent that it forces individual decisionmakers to account for the social cost of every mile traveled.[94]

Pricing mileage can happen through a road-usage fee (like a congestion toll) or through an annual fee (such as a mileage-specific vehicle registration fee). A road-usage fee is the best way to target traffic congestion, as the economic damages of delayed travel time are very specific to the location and time of day. For example, a dynamic congestion toll that changes hour-to-hour could price road usage only when an additional car would lead to much more traffic congestion. This incentivizes drivers to travel at times when the roads are likely to be least crowded, to use alternative routes, or to take fewer trips that are not essential. Alternatively, central business districts in large metropolitan areas, like New York City, can implement a congestion toll to target the places where traffic congestion is costliest. In its most extreme form, a congestion toll functions like a ban of cars. A number of cities are considering limited forms of this option in order to create pedestrian malls in urban areas.

Annual VMT pricing, however, can target traffic collisions and local air pollution well, as the damages are most directly proportional to annual VMT. The damages from these externalities increase with vehicle weight (increased risk-of-harm to others and damage to highway infrastructure) and vehicle age (increased local air pollutants and risk-of-harm to occupants). And so, a mileage fee that varies by these factors can further improve social welfare by providing incentives to travelers to use lighter, newer, and safer vehicles. This system could easily be adopted by state and local governments through the annual, or semi-annual, vehicle registration process. One limitation of annual VMT pricing, however, is the role of time preference. An individual will discount the cost of a mileage fee if it is imposed at a future date, and so will not internalize the cost of the mileage fee when deciding how many miles to travel. This suggests that semi-annual fees are better than annual mileage fees, and an instantaneous mileage fee is best if technologically possible.

As an example of the annual mileage fee, suppose external damages for traffic collisions and local air pollutants are approximately 10 cents per mile for a given make-year-model. If this vehicle travels 15,000 miles a year, the owner would have an annual fee of $1,500. Older and larger vehicles would pay a few more cents per mile. California, Oregon, Illinois and Washington have already considered a transition towards a mileage tax, in part to supplement lost revenues from a gas tax as EVs decrease the demand gasoline.[95] Differentiating this tax by vehicle weight and age can make these taxes more effective, with safer and more fuel-efficient vehicles being taxed at a lower rate.

Finally, absent a fuel-based policy to address transportation GHG emissions, it may be economically efficient for a mileage fee to differentiate by vehicle fuel type.[96] Less carbon-intensive vehicles, like EVs, would pay less per mile – perhaps even be subsidized. At the same time, more carbon-intensive vehicles would pay more per mile. This way, individuals and businesses would internalize the cost of more carbon emissions when choosing between different vehicles and how many miles to travel.

Infrastructure Investments Can Be Economically Optimal

Economic thinking is centered around marginal effects, such as the costs and benefits of an additional mile traveled or additional gallon of gasoline consumed. This is an important framework to understand the world and can be used to design policies that maximize welfare in the short run. As an unintended consequence, however, economic thinking is less suited to consider non-marginal changes such as long-run changes to infrastructure. The policies described in this section are "optimal," in the sense that they cause consumers to directly and fully internalize the external damages they presently ignore. But that behavior is largely conditional on existing infrastructure and public transportation options. Long-run analysis will show that improving public transportation and land use laws can be worthwhile approaches to reducing GHG emissions, and so, should not be ignored.[97] These long-run transitions of the transportation system and physical infrastructure can be funded in-part by the revenue collected from externality-correcting fees on fuel consumption and vehicle miles traveled.

IV. Policy Recommendations

Policymakers should consider three avenues for addressing the market failures described above: vehicle-based policies, fuel- or mileage- based policies, and infrastructure-based policies. For each one, this report discusses existing authority and possible new programs or statutory changes that could help address the market failures.

To truly reform surface transportation in the United States, it is necessary to pursue policy solutions along all three avenues – no single avenue can completely address all of surface transportation's economic harms as each market failure is determined in-part by different economic tradeoffs. Further, some policies are more effective when these avenues are pursued simultaneously. For example, better infrastructure that offers alternatives to single-passenger travel will increase the effectiveness of a fuel or mileage policy. Similarly, mileage pricing that differentially prices EVs, and prices fossil-fuels generally, can encourage the adoption of more fuel-efficient EVs by businesses and consumers.

While this report lays out various possible policy options, it does not purport to address all the possible legal arguments that could be made for or against each possibility. Instead, the report provides this overview in order to inform policy discussions of the programs that would be most beneficial from the economic perspective.

Accelerate the Transition to Fuel-Efficient Vehicles

Transitioning the fleet toward vehicles with low or zero tailpipe emissions – primarily by increasing the efficiency of vehicles with internal combustion engines (ICE) and increasing deployment of EVs – can reduce pollution from surface transportation and increase vehicle safety (although it will do little for traffic congestion). But that transition will require policy changes and new legislation. Existing statutory authority provides EPA with a number of tools to address this transition, including the ability to issue regulations that would reduce pollution emissions from new vehicles. However, some policy proposals may require the passage of new laws.

Transitioning the fleet will provide benefits beyond GHG reductions. It will help reduce local air pollutants, save consumers money at the pump, encourage "learning-by-doing," which in turn reduces the costs of new technologies (making future reductions less expensive); and increase vehicle safety by reducing the weight of average vehicles on the road and increasing the crumple space in vehicles.[98] And the policies that encourage deployment of EVs will create market demand for additional charging infrastructure, which can then contribute to a "network" effect that reduces the financial and convenience costs for future potential electric vehicle purchasers.

This section first establishes how to improve upon existing fuel economy standards. A more stringent fuel economy standard that directly regulates greenhouse gas emissions of new vehicles using a transparent market for credits is likely to provide the most benefits at the smallest cost. Beyond fuel economy standards, this section will discuss additional policies that can help accelerate the transition to cleaner, more fuel-efficient, vehicles that save consumers money.

Existing Regulatory Authority

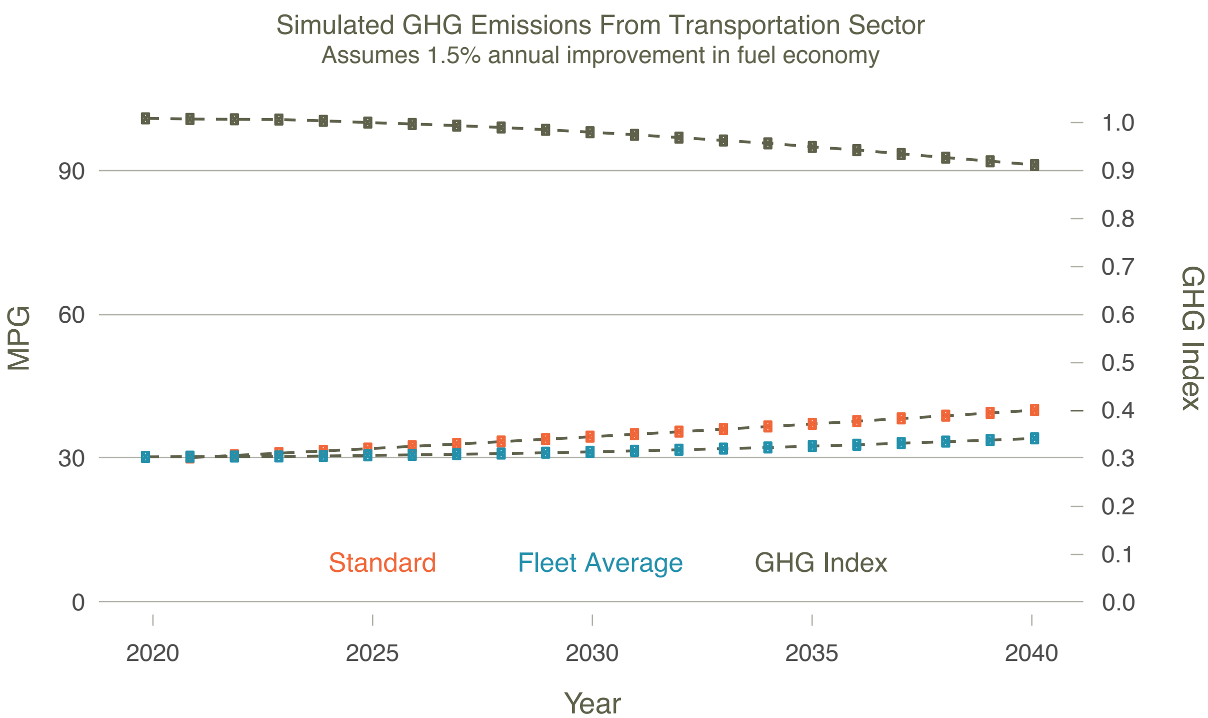
Extend and Improve Vehicle Emission Standards

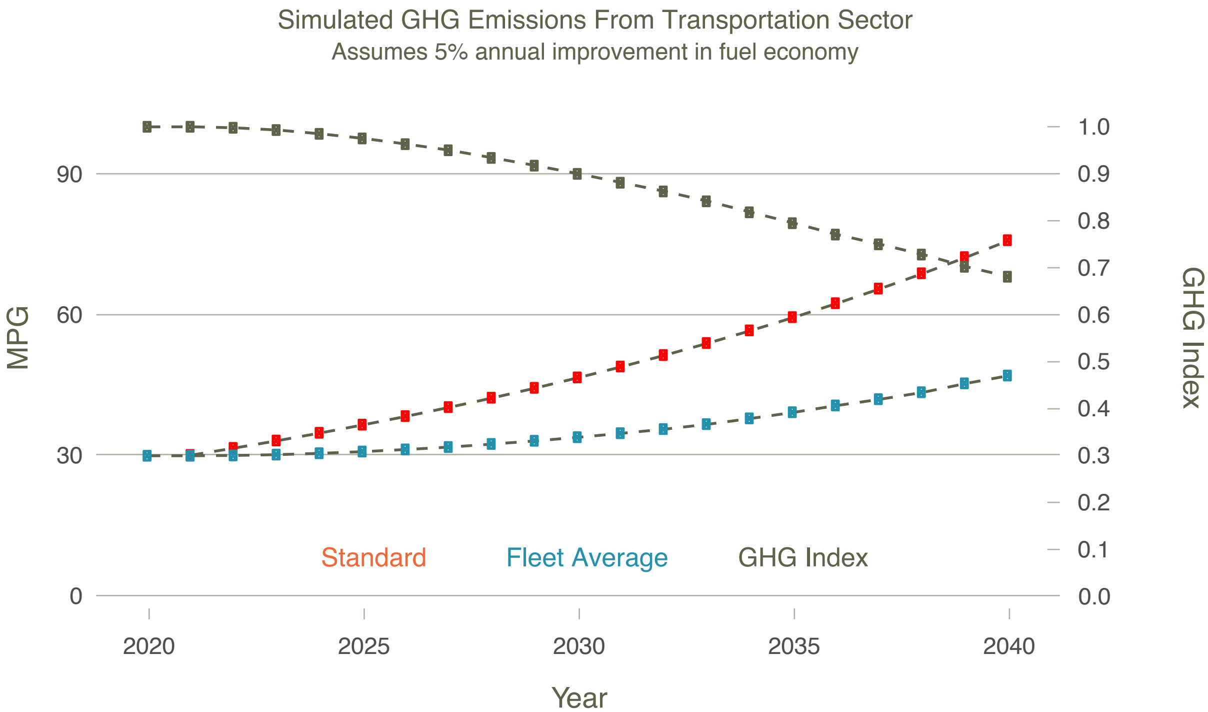
Section 202 of the Clean Air Act requires EPA to set standards for the emission of pollutants from *new* motor vehicles and engines that cause or contribute to air pollution that endangers health and welfare.[99] In 2009, EPA made the requisite "cause and contribute" and "endangerment" findings for the emission of GHGs.[100] And based on those findings, EPA set GHG emission rate limits (grams CO_2 emitted per mile driven) for various classes of vehicles.[101] EPA's authority to promulgate GHG emission standards for new motor vehicles has been upheld by the United States Court of Appeals for the District of Columbia Circuit, and the Supreme Court declined to review the issue.[102]

In 2012, EPA, in conjunction with the National Highway Traffic Safety Administration (NHTSA), updated the standards for cars and light trucks to require up to a 5% per year reduction in GHG emissions and improvement in fuel economy through Model Year 2025.[103] At that time, the agencies also committed to a "midterm evaluation" of the 2022–2025 portion of those standards, to be published "no later than April 1, 2018."[104] The agencies explained that they would use the midterm evaluation to evaluate the appropriateness of the 2022–2025 standards "based on an updated assessment of all the factors considered in setting the standards and the impacts of those factors on the manufacturers' ability to comply."[105]

EPA then conducted the mid-term evaluation, and on January 12, 2017, it issued a Final Determination,[106] finding that the standards were appropriate and would result in substantial improvements in economic welfare.[107] In addition, independent research has shown that the vehicle standards increase consumer welfare while reducing GHG emissions at a cost of $6 per metric ton of carbon dioxide.[108] However, in March 2020, EPA and NHTSA significantly weakened those standards, reducing the required rate of improvement to approximately 1.5% per year for model years 2021 to 2026.[109] A simple simulation of vehicle turnover shows the cumulative and compounding effect of the two standards on greenhouse gas emissions, over a 20-year time frame, in Figure 7.

Figure 7 – Simulated Fuel Economy Standards and Fleet-Wide GHG Emissions to 2040





A simple simulation showing how fuel economy standards of 5% or 1.5% differently affect fleet-wide GHG emission. Left hand axis shows miles per gallon, right hand axis is GHG emission indexed to 2020 levels. The simulation models a large fleet of light-duty vehicles. Fuel economy in the year 2020 is normally distributed around 30 mpg with a standard deviation of 3 mpg. Every year, a random proportion of the fleet (6%) is replaced with new vehicles. Fuel economy of the new vehicles is normally distributed with a mean equal to that year's standard mpg and a standard deviation of 3 mpg.

In order to align incentives better and take into account the external cost of vehicle emissions, EPA should, at a minimum, reinstate the ambitious – yet achievable – CO_2 standards set under the Obama administration. In addition, the agency should begin work immediately on the new set of standards for after 2025, taking into account progress in EV infrastructure and affordability as well as all the market failures outlined in this report.

Increasing the required year-of-year improvement in fuel economy is not the only way to improve existing fuel economy standards. There are a number of design features currently in place which could be improved upon. Instead, fuel economy standards could (*i*) move away from standards that are based on footprint or class of the vehicle, (*ii*) include a transparent credit market, and (*iii*) more explicitly and directly cap GHG emissions from new vehicle purchases. Each will be discussed in turn.

Footprint standards: Currently, EPA sets standards for each vehicle "model year," with different standards set by vehicle class (cars vs. light trucks and SUVs) and vehicle size (or "footprint"). Vehicles that have a larger footprint, or are part of a heavier class, need to meet a less stringent standard on average than those with a smaller footprint, or are part of a lighter class. As a result, the overall level of reductions will depend on consumer purchasing decisions.

EPA has largely done this to harmonize its standards with NHTSA fuel economy standards, which are required to be set based on an attribute such as vehicle size.[110] Section 202 of the Clean Air Act, in contrast, does not require EPA to set different standards by class or size.[111]

The advantage of attribute and class-based standards is that they provide consumers and automakers flexibility in compliance. In particular, a more lenient standard for larger vehicles reduces the cost of compliance for large vehicle manufacturers. Other justifications for the footprint-based standard may not be as strong, however. While some have argued that a larger vehicle has the potential to better protect its passengers in the case of a crash,[112] the argument associating a vehicle's mass with its occupant's safety is based on a weak statistical relationship.[113] In addition, these benefits also come with costs, as footprint incentives encourage automakers to sell, and consumers to buy, larger vehicles that tend to be less fuel-efficient.[114] What is more, larger vehicles can significantly increase the risk of harm to others in a collision, especially if the other party to the crash is a pedestrian or bicyclist.[115]

Moreover, there is mounting evidence to suggest that the benefits provided by attribute standards are overshadowed by problematic distortions to consumer and manufacturer decisionmaking.[116] A lenient standard for large-vehicle manufacturers is justified by economic theory only if auto manufacturers face additional challenges improving the fuel efficiency of larger vehicles, and each vehicle must meet its own fuel-economy standard.[117] Because section 202 standards incorporate an "averaging, banking, and trading" program, which allows large-vehicle manufacturers to achieve compliance through both average fleet performance and by purchasing compliance credits, there is limited-to-no economic rationale for basing the standards on some other attribute like footprint or weight.[118] For this reason as well as the harmful downsides of incentivizing larger vehicles, the EPA should consider moving away from its practice of setting different standards by class and size.

Credit markets: Setting a uniform standard does not mean that every vehicle is required to meet a specific emission-rate level. Section 202 standards incorporate an "averaging, banking, and trading" program – market-based measures in which vehicle manufacturers can average, bank, and buy/sell credits across time, manufacturers, and model types.[119] Maintaining such a program allows for flexibility similar to that afforded by attribute-based standards, and so decreases compliance costs overall. However, unlike footprint standards, an "averaging, banking, and trading" program does not necessarily decrease average fuel economy by incentivizing the production and adoption of larger, less fuel-efficient, vehicles.

Increasing the transparency of credit trading, by establishing and supporting a formal marketplace for credits, will decrease the compliance cost of any standard and even allow for a stricter standard for the same social cost. A transparent credit market places all players on equal informational footing, facilitates price discovery, and assists buyers and sellers in reaching terms.[120] All of these benefits would encourage mutually beneficial trades that decrease compliance costs. In spite of this, the current standard does not require or facilitate transparent prices and quantities in the compliance credit market.[121]

Greenhouse-gas emissions: Another improvement can be made by capping economy-wide GHG emissions induced by new vehicle purchases. If EPA's goal is to restrict GHG emissions from new vehicles then an economy-wide cap does this directly while also allowing for the trade of GHG-specific credits in a transparent market.[122] This type of cap-and-trade program for new vehicle GHG emissions does not exist at this time, but it would better guarantee emission reductions, provide benefits at a low cost and be straightforward to administer within the existing authority granted to the EPA under section 202 of the Clean Air Act.[123]

Under this program, the associated GHG emissions of each new vehicle sold would be based on the fuel efficiency of the vehicle, and the expected miles traveled by that vehicle.[124] Automakers would be required to retire compliance credits equal to the associated GHG emissions of each new vehicle sold. For example, automakers selling EVs powered by renewable energy need fewer compliance credits than automakers selling the same number of GHG-emission-intensive, high-mileage trucks.

These compliance credits could be freely distributed among automakers, auctioned off to generate revenue, or some combination of those two options. Because the total number of compliance credits would be limited and decrease over time, GHG emission reductions would be guaranteed – even more so relative to the existing standard which only regulates the average fuel economy of new vehicles.

This policy framework allows for great flexibility in compliance as it would retain the "averaging, banking, and trading" features of the existing GHG emissions standards program. In addition, because the program is truly technology neutral, alternative-fuel and fuel-efficient vehicles benefit from the program only in proportion to the outcome that matters: their relative reduction in lifetime GHG emissions. In this way, the program can achieve emission reductions at the lowest possible costs. Finally, this technology neutral option would also avoid the attribute-based issues outlined above.[125]

New Programs and Statutory Changes

There are several promising policies that might address the market failures discussed in this section and encourage a transition to energy-efficient vehicles. Although outside the scope of existing authority, these policies can help in decreasing GHG emissions and local air pollutants. For each, policy design features can increase the program's cost-effectiveness.

Directly Support Electric Vehicle Adoption

EVs provide great promise in reducing GHG and local air pollution. Several states have implemented subsidy programs that have encouraged electric vehicle adoption, the most effective of which are direct rebates at the time of purchase.[126] But despite that support, battery-based vehicles of all forms, including conventional hybrids, accounted for only 5% of the American new car market in 2018.[127] Consumers have limited incentive to purchase an electric vehicle so long as the EVs remain more expensive than their internal combustion equivalent, and manufacturers have little incentive to produce them given that fuel economy and emissions standards can be met without such technology, making them a costly compliance strategy. Thus for EVs to have any effect in the near term they need to be subsidized until they reach cost parity with traditional internal combustion engines.[128] Subsidies can be justified by economic principles, as a purchase subsidy addresses GHG and local air pollutant market failures in addition to the diffusion of network technology and learning-by-doing related market failures.[129]

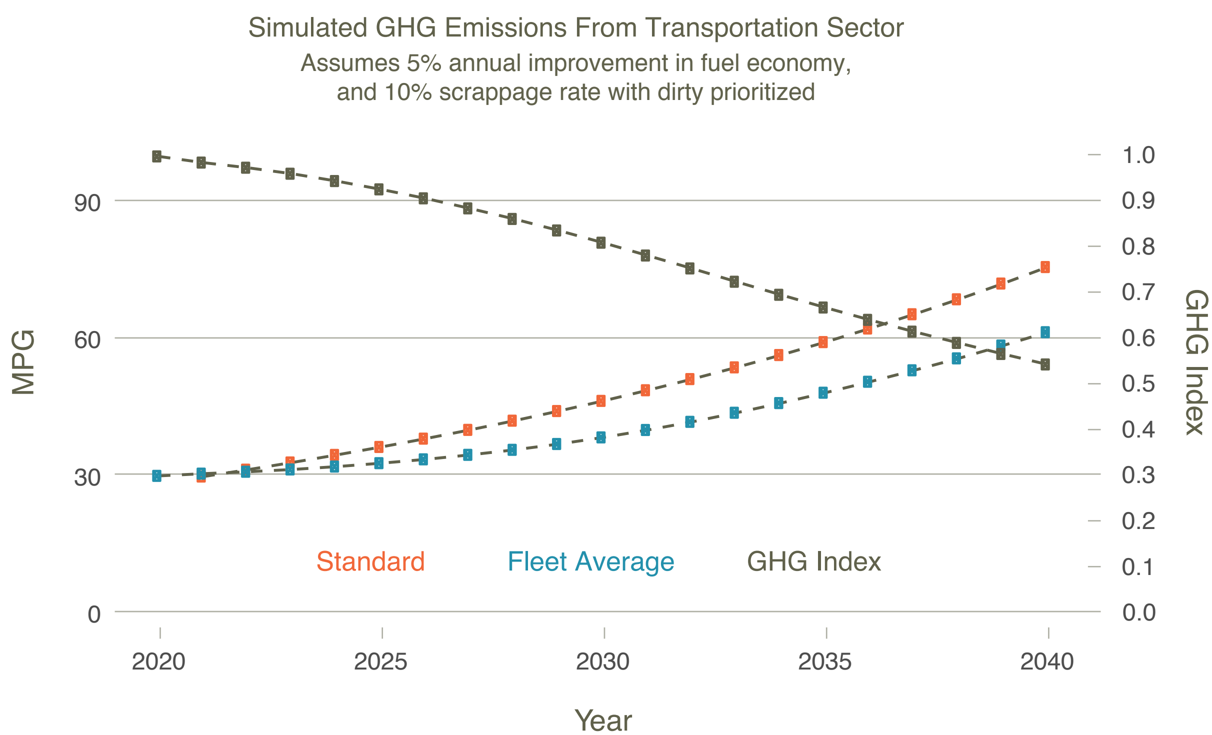
The federal government supports purchase of some EVs with a federal income tax credit of up to $7,500.[130] However, this tax credit is only available for the first 200,000 vehicles sold by each manufacturer. Some of these manufacturers have already exhausted all possible credits.[131] This has the effect of penalizing successful EV manufacturers and limiting the incentive for additional EV deployment. Congress should extend the tax credit beyond the current 200,000 vehicle limit. In addition, Congress should convert the subsidy into a more effective subsidy mechanism such as direct purchase rebates instead of an income tax credit because consumers are more responsive to immediate rebates than future tax credits.[132] Congress could also target the subsidy towards low-income consumers, which would be justified on efficiency and equity grounds, as these households are more responsive to changes in the new vehicle purchase price.[133] These purchase subsides can complement existing vehicle emission standards.[134]

Initiate a Scrappage Program Targeted at Heavy and Older Vehicles

Cars are durable goods and so the reduction in vehicle emissions will depend not only on the emission rate of new vehicles but also the retirement of old vehicles. Currently, only 7% of the fleet of vehicles in the United States are "scrapped" – taken off the road – each year.[135] Although existing policies and regulations for new vehicle purchases play an important role in addressing transportation market failures, they ultimately can only target a small fraction of all transportation-related market failures because they target only new vehicle purchases. Instead, policies directly targeted at the scrappage of fuel-inefficient, heavy, and older vehicles have the potential to more immediately mitigate the harm of many of transportations market failures.

Unfortunately, under Section 202 of the Clean Air Act, EPA only has authority to regulate new vehicles, not old ones.[136] This legal structure is known as "grandfathering"[137] and as is typical, produces significant problems. For example, if the new-vehicle rules lead to significantly increased prices, they can cause vehicle owners to keep their older, less-efficient vehicles for longer, and depending on maintenance costs and many other factors, could exacerbate some emissions gains.[138]

Figure 8 – Scrappage Policy and Fleet-Wide GHG Emissions to 2040



A simple simulation, similar to Figure 7, showing how a scrappage policy accelerates the reduction in fleet wide GHG emissions. Every year, the most fuel-inefficient vehicles are scrapped and replaced by new vehicles that meet that year's standard on average.

A program that encourages the replacement of the oldest and most emissions-intensive vehicles with new vehicles can counteract some of the effect of grandfathering and speed up the transition of the vehicle fleet, as demonstrated in Figure 8 with a simple simulation. For example, in 2009, as part of federal efforts to restart the economy during the economic recession, Congress created a "cash for clunkers" program that encouraged the scrapping of older vehicles.[139] Economic analyses have shown that this type of program can provide substantial consumer and economic benefits so long as it is properly designed.[140] Although the cost to abate GHG emissions under the 2009 program, net of reduced local air pollution benefits, was estimated to be above the Social Cost of Carbon – making it a more expensive alternative to a carbon tax – improvements made to the program design, coupled with the recent improvements in fuel economy, are likely to make this policy more cost-effective.[141]

Congress could adopt a similar program to encourage the scrapping of older, heavier, fuel inefficient domestic vehicles. For this policy to be effective, however, it needs to incentivize the purchase of vehicles that would not have been purchased absent the policy.[142] For this reason, purchase credits should be applied only towards the most fuel-efficient and safe vehicles, and the value of the credit should increase in proportion to the weight and emissions of the scrapped vehicle. The compensation for scrapping a vehicle should be in the form of subsidy towards the purchase of a new or used EVs or a voucher for use on public transportation. What is more, it should be verified these vehicles are permanently scrapped and recycled, and not exported to another country.[143]

Rein in Fuel Consumption and Miles Traveled

The advent of more affordable EVs provides great promise for decarbonizing the transportation sector, despite some uncertainty over when EVs will be able to perfectly replace all types of traditional internal combustion engine vehicles at an equivalent cost.[144] Absent significant electric vehicle adoption, to reduce the external damages from carbon emissions, and indirectly address all the other market failures from the transportation sector, it is important to price the damages caused by the combustion of fossil fuels by vehicles and/or by each additional mile traveled.

Putting a price on the combustion of fossil fuels or miles traveled is a way to ensure immediate reductions in GHG emissions and it can help alleviate the "grandfathering" problem that occurs when only new vehicles are subject to regulation. Because a policy that prices fossil fuel combustion by vehicles or directly prices VMT will incentivize a reduction in miles traveled, the co-benefits are likely to be large. The greatest obstacle to this policy is political feasibility.[145]

This section outlines the existing authority of EPA to establish a fuel-based program intended to reduce GHGs from the transportation sector. Although EPA has not acted on this authority, doing so would provide immense benefits to consumers, guaranteeing immediate reductions in GHG emissions and related economic harms. The report surveys a number of alternative statutory changes that could be used to address miles traveled and fuel consumption, available at nearly every level of governance in the United States.

Existing Regulatory Authority

Adopt a Federal Low Carbon Fuel Standard or Cap-and-Trade Program for Vehicle Fuels

The EPA could implement one of two potential fuel-based programs, either a low carbon fuel standard or a cap-and-trade program, which both have great potential to internalize the harm of transportation GHG emissions and could be implemented pursuant to EPA's existing Clean Air Act authority. The benefits of these programs include the immediate and guaranteed reduction in GHG emissions as well as the sizeable co-benefits of reduced local-air pollution, traffic congestion, and traffic collisions.

A low carbon fuel standard (LCFS) is a rate-based trading program designed to reduce the average carbon intensity, in terms of grams of GHG emissions per unit of energy, of all vehicle fuels – including electricity used to power EVs.[146] Fuels with a GHG intensity below the standard generate credits that can be sold to distributors of fuels with a GHG intensity above the standard. In this way, an LCFS acts as an implicit tax on more-GHG-intensive fuels, and an implicit subsidy for less-carbon-intensive fuels.

As for cap-and-trade programs, whereas an LCFS limits the *rate* at which vehicle fuels can produce carbon emissions, a cap-and-trade program limits the *total quantity* of vehicle-related carbon emissions that can occur in a given time period. Under such a program, a regulator sets the cap and then provides – either by auction, free allocation, or a combination of the two methods – a corresponding number of permits to fuel distributors. Each distributor must, at the end of a compliance period, hold a number of permits equal to the GHG emissions attributable to its fuel sales for that period. Even if permits are initially allocated at no cost, the ability to subsequently sell them to or purchase them from other distributors puts an implicit price on carbon emissions.

If set at a sufficiently stringent level, either an LCFS or an aggregate emissions cap could reduce emissions to the same degree as a carbon tax on vehicle fuels. In fact, estimates suggest that within the next 10 years, California's LCFS program (which can serve as a model for a national LCFS)[147] will approximate a fuel tax at the level of Social Cost of Carbon.[148]

Additionally, relative to EPA's existing Renewable Fuel Standards program, which sets annual use targets for particular types of biofuel, both LCFS and cap-and-trade programs have the advantage of being more technology-neutral. Approaches that are more technology-neutral are beneficial because they identify the lowest cost method of reducing GHG emissions, and do not require speculation on emission reduction potential of untested technologies. Thus, both LCFS and cap-and-trade programs minimize the aggregate cost of achieving a given level of GHG reduction by affording fuel distributors flexibility to adjust their compliance strategies over time in response to the introduction of new technologies or changes in the price of existing technologies.[149]

Because it limits average carbon emissions per unit of fuel, instead of total carbon emissions, an LCFS provides greater flexibility to respond to unexpected spikes in fuel demand.[150] A cap-and-trade program on the other hand, provides greater certainty as to the amount of emission reduction that will be achieved in a given compliance period but can lead to unexpectedly high or low compliance costs if the demand or supply of fuels exceed projections.[151]

Establishing either type of program is within EPA's existing statutory authority. Section 211(c) of the Clean Air Act permits the agency to "by regulation, control or prohibit the manufacture… or sale of any fuel or fuel additive for use in a motor vehicle, motor vehicle engine, or nonroad engine or nonroad vehicle if, in [its] judgment . . . any emission product of [a] fuel or fuel additive causes, or contributes, to air pollution . . . that may reasonably be anticipated to endanger the public health or welfare."[152] EPA may proceed with such regulation so long as it first considers "other technologically or economically feasible means of achieving emission standards under [section 202]."[153] Given the limits of section 202 emissions standards for new vehicles described above, including the grandfathering issue, EPA could reasonably determine that section 202 standards cannot sufficiently mitigate health and welfare harms associated with GHG emissions from vehicle fuels and that it is thus necessary for the agency to further reduce such emissions by implementing "control[s]" on fuel sales under section 211(c).

The Clean Air Act does not define "control" as it applies under section 211(c). However, EPA has previously used this section to establish market-based trading programs for pollution-producing components of vehicle fuels. In 1985, EPA established such a program for lead, which was ultimately upheld by the D.C. Circuit in 1987.[154] In 2000, EPA implemented a similar program for sulfur content as part of its Tier 2 Vehicle and Gasoline Sulfur Program.[155] Though such trading programs were built around rate-based limits, nothing in the text of Section 211 or related case law suggests that the provision could not similarly support the establishment of an aggregate emissions cap (i.e., a mass-based limit).[156] Nor does section 211 provide any express constraint on the stringency of "control" measures adopted under the provision. Thus, EPA has discretion to set an LCFS or emissions cap at a level that approximates the incentive effects of an efficient fuel tax and thus maximizes the regulatory program's net benefits.

New Programs and Statutory Changes

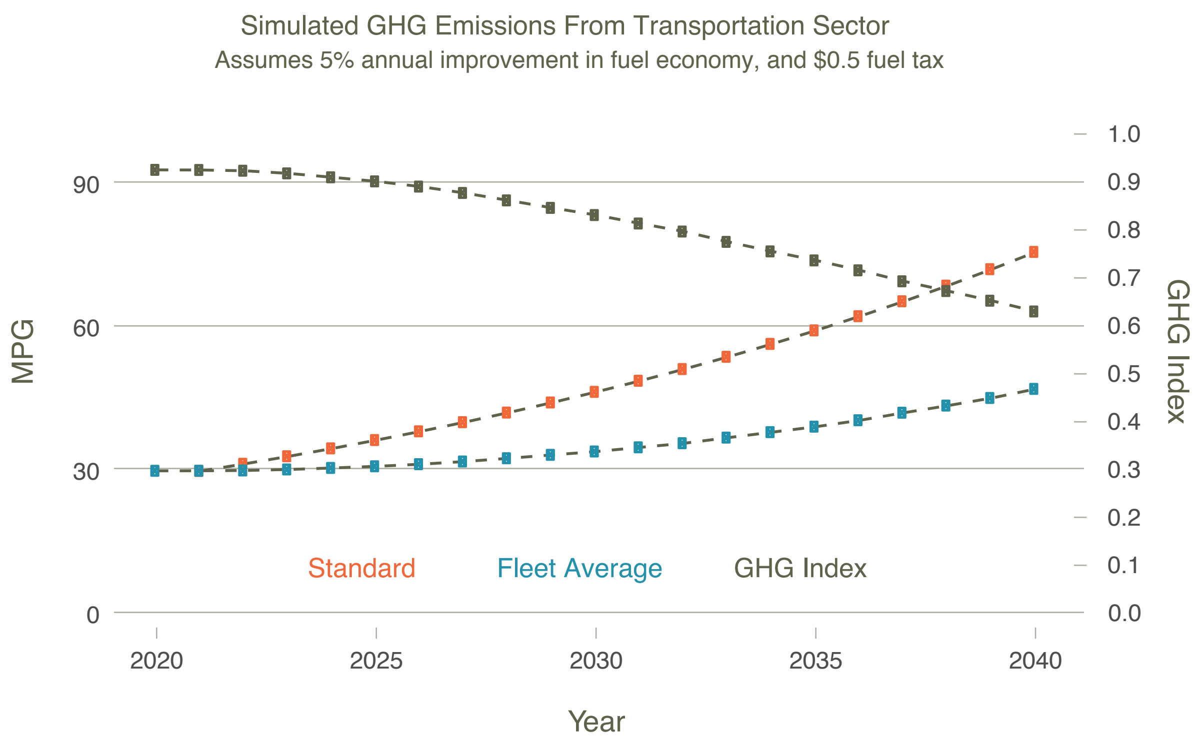
There are several promising policies that might address the market failures discussed in this section and reduce fuel consumption.

Update Federal Fuel Taxes

A fuel tax is an economically optimal option for addressing the market failures caused by fuel usage because it balances the costs and benefits of additional fuel consumption. The federal government imposes a tax on fuel. The current fuel tax is $0.18 per gallon of gasoline to fund highway maintenance.[157] This level has not been updated since 1993, and has not been adjusted for inflation.[158] Congress could pass a new statute that updates the federal fuel tax in order to reflect the external damage caused by fuel combustion and associated driving. At the same time, it would increase revenue for the Highway Trust Fund, which has been operating at a deficit and subsidized by general funds in recent years.[159] Figure 9 shows the immediate and lasting effect of a 50-cent increase in gasoline's price on fleet-wide greenhouse gas emissions using a simple simulation.

With the COVID-19 crisis, social-distancing measures have reduced demand for gasoline at least temporarily, consequently reducing the price of gasoline.[160] Even though the ongoing situation has placed a significant economic hardship on some households, a higher federal fuel tax is unlikely to add a large additional burden to consumers or businesses – especially if the tax is used to subsidize less carbon-intensive alternatives to driving a private vehicle.

Figure 9 – Fuel Tax and Fleet-Wide GHG Emissions to 2040



A simple simulation, similar to Figure 7, showing the anticipated change in greenhouse gas emissions from the introduction of a 50 cent per gallon tax. The simulation assumes a gas price of $2.50 per gallon and an elasticity of demand for fuel consumption of 0.4, consistent with the effects of a permanent price change estimated in Shanjun et al. supra note 93.

Restructure Annual Vehicle Registration Fees

Mileage fees are another promising option. In most states, vehicles must have an active registration for them to legally operate on public roads. As part of semi-regular updates to vehicle registration, departments of transportation in various states could easily require an odometer reading. With access to this data, it would be entirely feasible for state governments to impose a mileage fee as part of registering a vehicle, as described in section II.

Such a fee is potentially more equitable, efficient, and politically feasible than a fuel tax, especially if the mileage fee is differentiated by the externality per mile traveled.[161] For example, a higher mileage fee could be applied to older, heavier, less-safe, and fuel-inefficient vehicles that generate more emissions in a high-population-density area.

Among the states, Oregon has already moved towards mileage-based registration fees offering a template other states can follow.[162] Implementing such fees in other jurisdictions would likely require new legislation directing the Departments of Motor Vehicles (DMV) to charge registration fees per mile.[163]

Support Regional Cap-and-Invest Programs

Regional cap-and-trade programs can also provide some of the benefits of a more full-scale cap-and-trade program. Absent a federal fuel policy, states should consider joining a regional program to rein in fuel consumption such as the Transportation and Climate Initiative (TCI). In 2010, 11 participant-states launched TCI to "reduce GHG emissions, minimize our transportation system's reliance on high-carbon fuels, promote sustainable growth, address the challenges of vehicle miles traveled and help build the clean energy economy."[164] Effectively, the cap will assign a price to transportation fuel emissions that fluctuates with demand for transportation fuels. Recently, TCI has issued a Draft Memorandum of Understanding and conducted a modeling exercise showing $3 to $10 billion in health benefits by 2032 from reduced air pollution and traffic collisions.[165]

The TCI cap-and-trade program would also raise funds through the sale of allowances, which can be used to invest in transportation-sector emission reductions including a targeted scrappage program, public transportation, EV charging stations, EV purchase subsidies. This feature of the initiative guarantees a stream of green-transportation revenue for state and local governments.

Direct Transportation Infrastructure Spending Towards Net-Beneficial Investments

Infrastructure is a substantial determinant of vehicle-miles traveled and mode choice, and so is a determinant of all market failures in the transportation sector. When investing in transportation infrastructure, including highways, roadways, public transportation service, and the spatial distribution of housing and businesses, it is essential to consider all the relevant costs and benefits. Importantly, this includes a consideration of the implied greenhouse gas emissions and traffic congestion, as well as safety – especially for pedestrians.

This section establishes what improvements can be made with the existing authority granted to U.S. Department of Transportation (DOT), including better accounting of GHG emissions of transportation projects and targeting discretionary programs, and then broadly outlines new policies that can address market failures in the transportation sector.

Existing Regulatory Authority

The DOT is a major source of infrastructure funding, spending over $70 billion annually.[166] This spending primarily consists of transfers to state transportation agencies pursuant to programs authorized by Congress in multi-year combined authorization and funding laws.[167]

Though much of DOT's spending – including almost all of its highway spending – is allocated according to statutory formulas,[168] the agency has discretion to better track and mitigate the climate impacts of at least some programs. Specifically, DOT can and should (1) require accounting for GHG emissions as part of the National Highway Performance Program, and (2) require applicants for discretionary funding programs to conduct cost-benefit analyses quantifying and monetizing GHG emission impacts.

Require Accounting for GHG Emissions Associated with Federally Aided Highways

DOT should restore a GHG emissions measure to the National Highway Performance Program (NHPP). The NHPP, which accounted for more than half of federal highway spending between 2016 and 2020, requires DOT to establish performance criteria for state use of program funds.[169] States that fail to comply with these criteria receive only 65% federal support for a highway expenditure, significantly less than the 80-95% that is typically provided.[170]

In 2017, the Obama administration added a GHG measure to the NHPP criteria, requiring state departments of transportation to track annual tons of tailpipe carbon dioxide emissions, and then to set two- and four-year emissions goals.[171] Though achievement of these goals was not mandatory, DOT expected that states would "use the information and data generated as a result of the new regulations to inform their transportation planning and programming decisions."[172]

The 2017 rule, however, was never implemented, and the Trump administration repealed it in May 2018, citing the absence of "any statutory provision that specifically directs or requires [the Federal Highway Administration] to adopt a GHG measure."[173] The administration did not, however, dispute that DOT had *discretion* to require the measure. Indeed, the use of a GHG measure is entirely consistent with the NHPP's express goal of promoting the "environmental sustainability" of the federal highway system.[174] Thus, a future administration could and should restore the measure pursuant to DOT's existing authority.

Target Discretionary Spending at the Department of Transportation

Some of DOT's grant programs are discretionary rather than formulaic. That is, the agency has discretion to determine which states and projects receive the funds and, to some extent, the criteria by which funding applications are evaluated. Wherever permissible, DOT should require applicants to such programs to prepare a cost-benefit analysis that includes a properly quantified and monetized measure of the project's GHG impacts and prioritize funding for projects with the highest estimated net benefits.

For example, the Better Utilizing Investments to Leverage Development (BUILD) program for surface transportation capital projects and planning projects already requires grant applicants to submit cost-benefit analyses for their proposed projects.[175] However, DOT's current guidance on preparing such analyses recommends an indefensibly low estimate of the Social Cost of Carbon – inconsistent with the best available science.[176] Furthermore, DOT does not specify how the results of applicants' cost-benefit analyses inform its funding decisions.[177] To more efficiently allocate BUILD funds, DOT should, first, amend its Benefit-Cost Guidance for Discretionary Grant Programs to include a Social Cost of Carbon based on the best available science and, second, make the results of applicants' cost-benefit analyses an express criterion in its BUILD funding decisions. Doing so will likely reverse a recent trend, that has directed 50% of BUILD funding towards roads and away from transit and freight.[178]

DOT could take similar steps to improve its funding decisions under the Infrastructure for Rebuilding American (INFRA) program, which supports efforts to rebuild aging U.S. infrastructure and which also already requires applicants to submit a cost-benefit analysis.

New Programs and Statutory Changes

There are several promising policies that would shift transportation spending towards net-beneficial investments.

Support the Build-out of Electric Vehicles Charging Infrastructure

The number one concern preventing consumers from adopting EVs is the lack of public charging infrastructure.[179] Just like the transition to unleaded gasoline, it is unlikely that market forces alone will provide the right incentives to build refueling infrastructure.[180] Direct support for the build-out of electric vehicle charging infrastructure also addresses the network technology feature of EVs, and so can help kick-start adoption of EVs that would not have occurred absent a thick network of electric vehicle chargers.[181]

The Energy Policy Act of 2005 included a 30 percent investment tax credit for the installation of alternative fuel infrastructure, including electric vehicle charging infrastructure.[182] These credits expired in 2016, and have only recently been retroactively extended through the end of 2020.[183] Congress should extend this tax credit to beyond 2020, and prioritize commercial and public fast-charging stations as these provide the most benefit to consumers in need of charging on-the-go.

A national network of electric vehicle charging stations is essential to spur adoption of EVs and decrease greenhouse gas emissions. Aware of this fact, DOT has designated "alternative fuel corridors" along the interstate highway system.[184] This program largely provides official designation, organizational support, and signage identifying the corridor – but little more than that. Congress should support electric vehicle charging at federal highway rest stops along these corridors. This would require a change to federal law, which currently prohibits commercial activity in Interstate Highway rest areas as a condition of federal funding.[185]

Direct More Funding Towards Beneficial Public Transportation, Complete Streets, and Transit-Oriented Development

In 2014, total expenditure of highway infrastructure in the United States was nearly three times that spent on public transportation infrastructure.[186] Three-quarters of these funds come from the federal government through multi-year combined authorization and funding laws passed by congress. Directing more of these total funds towards public transportation in urban areas is likely to reduce harmful air pollution, traffic congestion, and traffic collisions.

The most recent bill passed by the House (not yet passed in the Senate), the INVEST in America Act, includes additional funding for public transportation infrastructure – and does the same for the interstate highway system.[187] Ideally, such a funding bill should reorient the focus of national expenditure away from highways and towards public transit, as the marginal value of each dollar spent on public transportation is more likely to address transportation market failures.

Besides federal support for expanded public transportation service, it is essential to support infrastructure that better connects people with jobs. Transit-oriented development, referring to a mix of commercial, residential, and office developments near public transportation hubs, broadly encompasses this idea. Currently, the DOT Federal Transit Authority provides technical assistance to federally funded public transportation projects seeking to promote transit-oriented development.[188] The INVEST in America Act expands upon a prior pilot program providing direct grants for transit-oriented development planning.[189] This is a great step in the right direction, and the Senate should include this program in the final legislation.

Finally, 20% of all traffic-related fatalities in 2018 were pedestrians, bicyclists, or other nonoccupants.[190] Simple changes to public infrastructure, including sidewalks, raised medians, elevated crosswalks, better bus stop placement, and general traffic-calming measures improve pedestrian safety.[191] Generally, these design features are captured under the idea of "complete streets," which include "road[s] … designed to be safe for drivers; bicyclists; transit vehicles and users; and pedestrians of all ages and abilities."[192] The INVEST in America Act supports complete streets in its updates to roadway design standard, and goes further to support a vision "towards zero" traffic related deaths.[193] The Senate should support both of these provisions in the final legislation.

V. Environmental Justice Considerations

Transportation externalities disproportionately harm low-income and minority communities, particularly with respect to local air pollution. When implementing policies to mitigate externalities associated with roadway travel, policymakers should also consider the disproportionate harmful impacts these market failures impose on low-income and minority communities. Taking environmental justice considerations into account and ensuring that the benefits and risks of government policies are fairly distributed across all communities, particularly when it comes to health and environmental impacts is a way to address these longstanding disparities.[194] Within the transportation sector, a policymaking approach rooted in environmental justice is necessary to ensure that future transit decisions work towards both correcting existing inequalities and preventing additional harm to communities that already bear the brunt of the market failures discussed in this report. Specific environmental justice policies can be employed to mitigate these disparities.

Disproportionate Impact of Externalities in Surface Transportation on Low-Income and Minority Communities

Local Air Pollution

Even though people living in low-income communities receive fewer benefits from most transportation improvements,[195] they are disproportionately exposed to the harmful effects of transportation, such as Transportation Related Air Pollutants.[196] This disparity is most extreme for low-income people of color, who experience higher levels of exposure than low-income white people.[197] Forced longer commute times and discriminatory policies that have led to a greater tendency to live in urban areas are driving factors contributing to these disparities.[198]

Increased exposure to Transportation Related Air Pollutants detrimentally affects people's health, educational and professional success, and propensity to commit violent crime, all of which reinforce the cycle of poverty and lead to additional societal costs.

In particular, exposure to Transportation Related Air Pollutants has been linked to more hospital visits for asthma, respiratory conditions, and heart problems.[199] While young children and the elderly are most sensitive to Transportation Related Air Pollutants and therefore more likely to suffer from these health problems, greater exposure to Transportation Related Air Pollutants also affects the respiratory and heart health of adults ages 20 to 64.[200] Across 12 California communities near airports, days with higher levels of Transportation Related Air Pollutants are associated with $540,000 in additional medical expenses *per day*.[201]

Exposure to Transportation Related Air Pollutants can also negatively affect academic and professional success. A study analyzing the effects of $PM_{2.5}$ and CO on high school students taking standardized tests found that greater levels of these pollutants on testing days led to a noticeable drop in scores.[202] Beyond just short-term effects on test scores, air pollution can also have a long-term impact on academic success given the importance of these tests for university entry, major selection, etc.[203] Higher levels of air pollution are also associated with greater levels of school absenteeism for children, suggesting further impediments to academic success.[204] Additionally, increased exposure to air pollutants reduces the number of hours adults are able to work, perhaps in part due to increased health problems and hospitalizations.[205]

Lastly, short-term exposure to higher levels of Transportation Related Air Pollutants increases rates of violent crimes. A study compared crime rates on two sides of a major highway and found that on any given day, the side downwind from air pollution sources experienced an average 2.2% increase in violent crime.[206] The study did not find any correlation between greater exposure to air pollution and property crime rates, however.[207]

Other Externalities

Beyond local air pollution, market failures such as greenhouse gas emissions, traffic congestion, and traffic collisions also disproportionately affect low-income and minority groups.

In particular, higher levels of GHGs accelerate climate change, which lower-income and minority groups suffer from the most. Climate change increases the frequency of extreme heat waves and flooding, which primarily affect low-income communities.[208] Additionally, low-income people and people of color are more financially constrained when it comes to mitigating the harmful effects of climate change, either by purchasing resources like flood insurance and air conditioning or relocating to areas less prone to natural disaster.[209] The unfairness of this disproportionate climate change burden is further heightened given that minority groups are less responsible for GHGs and resulting climate change effects.[210] On average, African American households emit 20% less carbon dioxide than white households.[211]

Additionally, low-income people are more likely to be involved in pedestrian traffic collisions. This in part stems from the fact that low-income groups are more likely to live in areas with high residential density or mixed land use (i.e., where trade, public buildings, and residences all coexist).[212] Similarly, low-income groups are more likely to live in urban areas near major roadways and with heavy traffic flow, which increases exposure to vehicles on a daily basis.[213] The design of roadways in lower-income areas also plays a role. Four-way intersections are much more likely to lead to crashes than three-way or T-intersections and they are more prevalent in low-income communities versus wealthy communities.[214]

Lastly, low-income communities suffer greatly from increased traffic congestion. Because many low-income people cannot afford cars, they rely on public transportation to access jobs, healthcare, and schools.[215] Increasingly, bus transit is the main public transportation option available in these communities.[216] This is due in part to a recent increase in poor populations in the suburbs, where central public transit options like subways and bikeshares are unavailable.[217] Additionally, many new public transportation hubs have been placed primarily in affluent areas.[218] While individual bus riders contribute less to overall traffic congestion than those who choose to travel by car, they still suffer more when traffic hits.[219] Buses delayed due to traffic lead to inaccurate arrival information, bus bunching, and overcrowding, all of which prolong time spent commuting and waiting before even getting on the road.[220]

Policy Recommendations

Since the environmental justice movement first began in the 1980s, various policy recommendations have been considered to ensure that disadvantaged groups are not disproportionately affected by government actions.[221] There are two main types of environmental justice policies, both of which are necessary to ensure equity in transportation decision-making: procedural policies and substantive policies.[222] For the most part, these recommendations apply generally across different types of transportation decisions and can be utilized to address many or all of the externalities described herein.

Procedural Policy Recommendations

Over the years, greater public involvement in government decision-making processes, particularly among disadvantaged groups, has been shown to be as an effective tool to address environmental justice concerns. The Department of Transportation has recognized the importance of this measure to ensure that the interests of all groups that may be affected by a particular transportation proposal are acknowledged.[223] This is particularly relevant for marginalized groups that have historically been excluded from participating in transportation-related decisions and which have accordingly shouldered more of their costs.[224]

Specific policy recommendations to encourage broader and more diverse public participation include (1) developing strategies to identify and engage with more diverse community groups throughout the planning and decision-making process and (2) withholding certification of planning projects unless they incorporate underserved communities in the public involvement process.[225] At the federal level, authority to implement these strategies rests with the Department of Transportation.[226] At the state and local level, this authority typically rests with Metropolitan Planning Organizations.[227]

Federal agencies may also have authority to implement these public participation strategies for state and local projects that receive federal funding. For state and local highway projects that receive federal funding as Federal-Aid Projects, the Federal Highway Administration ("FHWA") is required to create an Oversight Program for each project, which "at a minimum, shall be responsive to all areas relating to financial integrity and project delivery."[228] Using this authority, FHWA could potentially require state and local authorities to comply with these environmental justice policies. Similarly, state and local public transportation projects that receive funding under the Capital Investment Grant program ("CIG") are required to submit project proposal plans to the Federal Transit Authority ("FTA") in accordance with the Fixing America's Surface Transportation ("FAST") Act.[229] Projects seeking funding pursuant to CIG are required to demonstrate that the project is "justified" based on a number of criteria including mobility improvements, environmental benefits, congestion relief, economic development, and estimated ridership.[230] FTA could use its project approval authority to require state and local governments to implement public participation measures in order to comply with these CIG FAST Act criteria.

Additionally, groups charged with making transportation decisions can elect strategic community representatives to their boards to facilitate public outreach, such as coalitions that advocate for community involvement in smart growth and environmental justice like The Transportation Equity Network of the Center for Community Change or the Funders' Network for Smart Growth and Livable Communities.[231]

While policies that increase and diversify public participation are crucial, it is important to recognize the limits of these measures.[232] Additional policies, such as an explicit mandate that transportation agencies initiate their own research into the impact of potential decisions on disadvantaged communities, are necessary to ensure that the interests of these groups are recognized in the transportation planning process.[233] For example, Executive Order 12898 requires federal agencies to develop internal programs that "identif[y] and address[] disproportionately high and adverse human health or environmental effects" of their projects and policies.[234] Similarly, The Transportation Equity Act for the 21st Century ("TEA-21") requires Metropolitan Planning Organizations to develop participation plans that include a description of strategies for "[s]eeking out and considering the needs of those traditionally underserved by transportation systems, such as low-income and minority households, who may face challenges accessing employment or other services."[235]

While procedural policies such as these are important on a symbolic level, they alone have not been effective in reducing disproportionate harmful impacts of recent government actions on low-income and minority groups.[236] An approach that goes beyond symbolic gestures and adopts policies that also substantively benefit low-income and minority groups is necessary to meet environmental justice goals.

Substantive Policy Recommendations

Given the proximity of many low-income and minority communities to major thoroughfares and their reliance on bus transportation, replacing internal combustion trucks and buses with electric alternatives could significantly decrease both GHGs and the level of Transportation Related Air Pollutants in these areas.[237] While encouraging widespread adoption of EVs among private drivers would also likely improve air quality in low-income communities, government programs geared towards this goal so far have primarily been utilized by higher income car purchasers rather than car purchasers living in low-income areas.[238] Accordingly, environmental justice goals would be more efficiently and effectively served by focusing on heavy-duty buses and trucks, while also targeting electric vehicle purchase subsidies towards lower-income and minority households or neighborhoods.

Policymakers could also address environmental justice concerns related to surface transportation market failures by improving public transit services and providing these at a discount (or for free).[239] Because low-income communities tend to rely on public transportation more than wealthier communities, focusing on these forms of transit rather than highway expansions would both level the accessibility playing field between these groups and avoid increased emissions from adding more private cars to the road.[240] By taking more drivers off the roads, particularly if commuters who can afford private car transportation are incentivized to use public transit instead, these measures would likely reduce local air pollution in low-income communities, GHG emissions, traffic congestion, and traffic collisions. Additional measures to improve low-income access to public transportation include subsidizing on-demand services to take people to transit stations and improving the connectivity of existing and new transit stations.[241]

Lastly, state and federal governments could implement fuel and VMT taxes and direct the corresponding tax revenue towards low-income and minority communities. These policies not only disincentivize driving generally, but also force drivers themselves to internalize the social costs of their travel (as discussed earlier).[242] Low-income groups would benefit disproportionately from the overall reduction in local air pollution, climate change effects from greenhouse gas emissions, traffic congestion, and traffic collisions that would result from lower driving rates. Given that low-income and minority groups are less responsible for contributing to these transportation-related health and safety externalities, policies like fuel and VMT taxes appropriately place the burden of reform on wealthier groups that are more responsible. Doing so would be a step forward in correcting the current mismatch between the benefits and burdens of transportation. It is essential, however, that the revenue from fuel and VMT taxes be used to offset the burden fuel and VMT fees place on low-income and minority communities – by investing in cleaner technologies and public transportation initiatives discussed above, or even in a general wealth transfer – as doing so is crucial to ensuring these are progressive policies that correct for environmental injustices.

VI. Conclusion

Surface transportation in the United States is in dire need of reform. Due to GHG emissions, local air pollutants, traffic congestion, and traffic collisions, the true costs of transportation can at times eclipse the benefits provided. Quantifying the damages of these market failures can help inform policy solutions.

Economically efficient policies to address these market failures include a fuel fee of roughly 50 cents per gallon of gasoline, and a mileage fee of roughly 10 cents per mile. Differentiating the mileage fee by vehicle weight, size, and age increases social welfare.

Legal and political roadblocks could make it difficult to implement the economically optimal policies – but there are several other options for policymakers that would be beneficial for Americans. Moreover, no single avenue can solve all of the problems associated with the transportation sector. Instead, a unified approach that simultaneously considers the many market failures in surface transportation is more likely to increase welfare at a low cost to society. In particular, a comprehensive transportation policy includes well-designed vehicle-, fuel-, and infrastructure-based policies.

Finally, market failures in the transportation sector place an unequal burden on already disadvantaged groups largely in the form of local air pollution. Policymakers should consider the distribution of benefits when evaluating alternative transportation policies and adopt both procedural and substantive changes to ensure a more just outcome.

Summary of Policy Recommendations

* denotes policy is permissible under existing authority

Recommendations to Federal Policymakers:

Accelerating the Transition to Fuel Efficient Vehicles

**Extend and Improve Vehicle Emission Standards*

- Reinstate ambitious, yet-achievable, vehicle GHG emission standards. Consider improving on the design of the standards by (*i*) rescinding class- and attribute-based features, (*ii*) establishing a transparent marketplace for compliance credits, and (*iii*) directly limiting the lifetime GHG emissions of new vehicle sales.

Directly Support Electric Vehicle Adoption

- Extend federal purchase subsides for electric vehicles beyond the first 200,000 vehicles sold by each manufacturer. Target the subsidies towards more price responsive low-income households.

Initiate a Scrappage Program Targeted at Heavy and Older Vehicles

- Target the scrappage of vehicles that disproportionately generate more local air pollution and additional risk-of-harm to others. Value the credit of each scraped vehicle in proportion to its weight and emissions. Apply the scrappage credit only towards the most fuel-efficient vehicles or alternatives to passenger vehicles.

Reining in Fuel Consumption and Vehicle Miles Traveled

**Adopt a Federal Low Carbon Fuel Standard or Cap-and-Trade Program for Vehicle Fuels*

- Establish either fuel-based program – both of which can guarantee immediate emission reductions and provide sizable co-benefits by reducing total vehicle miles traveled.

Update Federal Fuel Taxes

- Increase the federal fuel taxes to reflect the monetized damages of GHG emissions, inflation since 1993, and to guarantee funding for the Highway Trust Fund.

Direct Transportation Infrastructure Spending Towards Net-Beneficial Investments

**Require Accounting for GHG Emissions Associated with Federally Aided Highways*

- Stipulate that quantification of tailpipe GHG emissions is required for federal funding for highways through the National Highway Performance Program.

**Target Discretionary Spending at the Department of Transportation*

- Encourage cost-benefit analysis for discretionary spending that properly monetizes each project's GHG impacts. Prioritize funding for projects with the highest estimated net benefits.

Support the Build-out of Electric Vehicle-Charging Infrastructure

- Extend investment tax credit for alternative fuel charging infrastructure beyond 2020. Establish electric vehicle charging infrastructure at rest stops along designated "alternative fuel corridors."

Direct More Funding Towards Public Transportation, Complete Streets, and Transit-Oriented Development

- Legislate federal funding towards public infrastructure that provides benefits to passengers not traveling by car and reduces dependence on private vehicle travel.

Additional Recommendations to State Policymakers:

Reining in Fuel Consumption and Vehicle Miles Traveled

Restructure Annual Vehicle Registration Fees

- Structure annual vehicle registration fees in proportion to annual miles traveled. Differentiate the per-mile rate by the weight and age to mitigate the harms of traffic collisions and local air pollution.

Support Regional Cap-and-Invest Program

- Participate in regional initiatives that are designed to limit total fuel consumption, like the Transportation and Climate Initiative, to guarantee GHG emission reductions and generate a steady stream of revenue to achieve state transportation goals.

Endnotes

1 See the introduction for a complete definition of a market failure. This is distinct from regulatory failures, where regulatory policy distorts individual decision making away from what is best for society. This, too, is a problem in the transportation sector; *see generally* Gregory H. Shill, *Should Law Subsidize Driving?*, 95 N.Y.U. L. Rev. 498 (2020) (summarizing the ways in which the law overlooks and encourages the social harms of driving in the United States.).

2 *See* Bureau of Transp. Statistics, U.S. Vehicle-Miles, https://www.bts.gov/content/us-vehicle-miles (showing highway and transit travel account for 98.7% of all vehicle miles traveled in 2018).

3 *See* Ian W.H. Parry, Margaret Walls, & Winston Harrington, *Automobile Externalities and Policies*, 45 J. Econ. Lit. 373 (2007). This report follows Parry et al. in focusing our attention on greenhouse gas emissions, local air pollution, traffic congestion, and traffic collisions. The harms of these market failures are the largest in magnitude. The report discusses other market failures briefly in section I.

4 *See generally* Ove Hoegh-Guldberg et al., *Impacts of 1.5°C on Natural and Human Systems*, Intergovernmental Panel on Climate Change (2018), https://www.ipcc.ch/site/assets/uploads/sites/2/2019/02/SR15_Chapter3_Low_Res.pdf.

5 *See* U.S. Dep't of Transp., Fed. Highway Admin., Summary of Travel Trends 2017 National Household Travel Survey, at 16 (2017), https://nhts.ornl.gov/assets/2017_nhts_summary_travel_trends.pdf; U.S. Envtl. Prot. Agency, *Fast Facts: U.S. Transportation Sector Greenhouse Gas Emissions 1990-2017*, at 2 (June 2019), https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100WUHR.pdf.

6 *See, e.g.,* U.S. Envtl. Prot. Agency, Green Vehicle Guide: Light Duty Vehicle Emissions, https://www.epa.gov/greenvehicles/light-duty-vehicle-emissions#standards (last updated Sept. 24, 2019).

7 *See* Tex. A&M Transp. Inst., Urban Mobility Report 2019, https://mobility.tamu.edu/umr/congestion-data/ (last visited June 30, 2020).

8 *See* Gilles Duranton & Matthew A. Turner, *The Fundamental Law of Road Congestion: Evidence from U.S. Cities*, 101 Am. Econ. Rev. 2616, 2645 (2011).

9 *See* U.S. Dep't of Transp., Nat'l. Highway Traffic Safety Admin., 2018 *Fatal Motor Vehicle Crashes: Overview*, at 1 (Oct. 2019), https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812826.

10 *See* U.S. Dep't. of Transp., *2020 Budget Highlights*, https://www.transportation.gov/sites/dot.gov/files/docs/mission/budget/333126/budgethighlightsfinal040519.pdf.

11 *See* U.S. Envtl. Prot. Agency, *supra* note 6.

12 *See generally* Ove Hoegh-Guldberg et al., *supra* note 4.

13 *See generally* Parry et al., *supra* note 3; *see also* Ian W.H. Parry & Kenneth A. Small, *Does Britain or the United States Have the Right Gasoline Tax?*, 95 American Economic Review 1276, 1276 (2005).

14 *See, e.g., New Jersey Energy Master Plan, Pathway to 2050* at 12 (2019), https://nj.gov/emp/docs/pdf/2020_NJBPU_EMP.pdf (showing "Reduce Energy Consumption and Emissions from the Transportation Sector" as strategy number 1 to achieve New Jersey's goal of 100% clean energy by 2050).

15 *See generally* Daria Roithmayr, *Reproducing Racism: How Everyday Choices Lock in White Advantage* (NYU Press 2014); Douglas S. Massey & Nancy Denton, *American Apartheid: Segregation and the Making of the Underclass* (Harvard University Press 1993).

16 *See* Gregory N. Mankiw, *Principles of Microeconomics* 136 (2006).

17 *Id.* at 151.

18 *Id.* at 9.

19 *See, e.g.,* Thomas F. Stocker et al. eds., *Climate Change 2013: The Physical Science Basis, Intergovernmental Panel on Climate Change*, at 1535 (2013), https://www.ipcc.ch/site/assets/uploads/2018/02/WG1AR5_all_final.pdf.

20 *See generally* Hoegh-Guldberg et al., *supra* note 4.

21 Some existing policies discourage transportation activities that produce more greenhouse gas emissions, as described in more detail in Section III. However, these are justified by other market failures or are inadequate in scope as currently promulgated. For example, in the US a federal benefits tax of 18 cents per gallon increases the price of gasoline, discouraging its consumption. This is largely justified by the public goods problem of transportation highway infrastructure. *See* John Chynoweth Burnham, *The Gasoline Tax and the Automobile Revolution*, 48 Miss. Valley Hist. Rev. 435 (1961). Relatedly, the federal vehicle greenhouse gas standards encourage the adoption of more fuel-efficient vehicles. In their current form these federal policies fail to accurately mitigate the harm of more greenhouse gas emissions in the transportation sector. *See generally* Inst. for Policy Integrity, *Key Economic Errors in the Clean Car Standards Rollback* (2020) (showing the economic errors that make the current rule inconsistent with sound economic analysis); Bethany Davis Noll, Peter Howard, Jason Schwartz, & Avi Zevin, Inst. for Policy Integrity, *Shortchanged: How the Trump Administration's Rollback of the Clean Car Standards Deprives Consumers of Fuel Savings* (2020) (illustrating shortcomings in the current rule).

[22] *See* Mankiw, *supra* note 16, at 197.

[23] *See* U.S. Envtl. Protection Agency, *supra* note 6 (showing that CO_2 was 97% of the transportation greenhouse gas emissions global warming potential in 2017. These values do not include international travel and shipping, or upstream GHG emissions from exploration, production, transportation, and refining of petroleum. US EPA, GHG Reporting Profiles, 2014, report petroleum refining is an additional 144 million metric tons of CO_2 (7% over transportation's total GHG emissions)).

[24] *See id.*

[25] *See id.* at 4.

[26] The can be verified with the following identity:
Tons of GHG = A B C
$$\text{Tons of GHG} = \text{Miles Traveled} \quad \frac{\text{Energy}}{\text{Miles Traveled}} \quad \frac{\text{Tons of GHG}}{\text{Energy}}$$

[27] Demand for travel can also be determined by fuel economy. As fuel economy improves, traveling the same distance requires less fuel expenditure. This is referred to as the "rebound effect," and is an area of active research. *See* Antonio Bento, Mark Jacobsen, Christopher Knittel, & Arthur van Benthem, *Estimating the Costs and Benefits of Fuel-Economy Standards*, 1 Environmental and Energy Policy and the Economy 129, 149 (2020); *see also* Inst. For Policy Integrity, *Comments Re: The Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Model Years 2021-2026* at 99-125 (Oct. 26, 2018), https://policyintegrity.org/documents/Emissions_Standards_EPA_NHTSA_Comments_Oct2018.pdf.

[28] Conventional fossil fuel vehicles measure fuel efficiency in Miles per Gallon. The measure used by the EPA for electric vehicles is Mile Per Gallon Equivalent, which measures the miles traveled per unit of energy equivalent to a gallon of gasoline. *See* U.S. Envtl. Protection Agency, *New Fuel Economy and Environment Labels for a New Generation of Vehicles*, EPA-420-F-11-017 (May 2011). Most Electric vehicles have a MPGe over 100, while the MPG of the 2018 new vehicle fleet was 25.1 MPG. U.S. Envtl. Protection Agency, *Executive Summary of The 2019 EPA Automotive Trends Report: Greenhouse Gas Emissions, Fuel Economy, and Technology since 1975*, at ES3 (Mar. 2020), https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100YVK3.pdf.

[29] Greenhouse gas emissions can also be generated by non-travel related features of automobiles, like air-conditioning and idling technologies. *See* U.S. Envtl. Protection Agency, Greenhouse Gas Emissions from a Typical Passenger Vehicle, EPA-420-F-18-008, (2018), at 2. If the greenhouse gas emissions these features generate are relatively constant per mile traveled, they can be considered a determinant of the efficiency of travel.

[30] *See* U.S. Envtl. Protection Agency, Emission Factors for Greenhouse Gas Inventories, https://www.epa.gov/sites/production/files/2018-03/documents/emission-factors_mar_2018_0.pdf (last modified Mar. 9, 2018). This ignores upstream emissions from gasoline production, which can vary depending on how it is processed.

[31] *See* U.S. Envtl. Protection Agency, *supra* note 29; *see also* U.S. Energy Info. Admin., Carbon Dioxide Coefficients (Feb. 2, 2016), https://www.eia.gov/environment/emissions/co2_vol_mass.php. Corn ethanol has roughly the same lifecycle GHG emissions as gasoline. GHG from electricity depends on the corresponding fuel source. *See* U.S. Dep't of Energy, Greenhouse Gas Emissions from Electric and Plug-In Hybrid Vehicles, https://www.fueleconomy.gov/feg/Find.do?action=bt2 (last visited June 30, 2020) (showing zip-code level CO_2 grams-per-mile that take into account the local mix of fuels used to generate electricity).

[32] Since the collapse of coal power and the rise of renewable energy, electric vehicles emit less greenhouse gas emissions than conventional internal combustion engine vehicles almost everywhere in the United States. *See* Stephen P. Holland, Erin Mansur, Nicholas Z. Muller, & Andrew J. Yates, Decompositions and Policy Consequences of an Extraordinary Decline in Air Pollution from Electricity Generation (Powerpoint Presentation 2019), https://energy.umich.edu/te3/wp-content/uploads/sites/2/2019/10/Holland-slides-TE3-2019.pdf. To compare electric vehicles to traditional vehicles, you need a measure of efficiency, such as MPGe, and a measure of the local electricity fuel mix. *See* U.S. Envtl. Protection Agency, *supra* note 29; U.S. Dep't of Energy, Greenhouse Gas Emissions from Electric and Plug-In Hybrid Vehicles, https://www.fueleconomy.gov/feg/Find.do?action=bt2 (last visited June 30, 2020) (providing a tool to calculate the greenhouse gas grams per mile for every electric vehicle make-year-model by zip code in the United States).

[33] *See* U.S. Energy Info. Admin., Annual Energy Outlook 2020 (Powerpoint Presentation, 2020), https://www.eia.gov/outlooks/aeo/pdf/AEO2020%20Transportation.pdf (showing a decrease in transportation GHG emissions until 2040, primarily because fuel economy standard improvements. By mid-century, however, transportation GHG emissions start increasing because the EIA models VMT rising year-over-year.).

[34] This number reflects the IWG's Social Cost of Carbon in 2020 using a 3% discount rate inflated to 2019 dollars. Though the Trump administration withdrew the IWG's technical support documents, experts continue to recommend that agencies rely on the IWG's estimates as the best available estimates for the monetized damages associated with an additional ton of CO_2 emissions. Richard Revesz et al., *Best Cost Estimate of Greenhouse Gases*, 357 Sci. 655, 655 (2017); Exec. Order No. 13,783 § 5(b), 82 Fed. Reg. 16,093 (Mar. 28, 2017).

[35] *See* Institute for Policy Integrity, Issue Brief: A Lower Bound: Why the Social Cost of Carbon Does Not Capture Critical Climate Damages and What That Means for Policymakers (2019).

[36] *See* U.S. Energy Info. Admin., *supra* note 33; U.S. Envtl. Protection Agency, *supra* note 29.

[37] *See* U.S. Envtl. Protection Agency, *supra* note 6, at 3 (note, however, that this ignores any upstream of downstream GHG emissions, or the emissions of other greenhouse gas emissions from transportation vehicles).

[38] *See* Revesz et al., *supra* note 34.

[39] U.S. Gov't Accountability Off., GAO-14-663, Regulatory Impact Analysis: Development of Social Cost of Carbon Estimates, 12-20 (2014), https://www.gao.gov/products/gao-14-663. The Social Cost of Carbon has also been adopted in a number of states. *See* Inst. for Policy Integrity, The Cost of Carbon Pollution: States Using the SCC, https://costofcarbon.org/states (last visited Mar. 17, 2020).

[40] *See supra* note 35

[41] *See, e.g.,* U.S. Envtl. Protection Agency, Version 1 of The 2014 National Emissions Inventory Report, at Fig. 6 (Apr. 2017), https://www.epa.gov/sites/production/files/2017-04/documents/2014neiv1_profile_final_april182017.pdf.

[42] *See* U.S. Envtl. Protection Agency, EPA/600/R-08/139F, *Integrated Science Assessment for Particulate Matter* (2009); Wes Austin, Garth Heutel, & Daniel Kreisman, *School Bus Emissions, Student Health and Academic Performance*, 70 Econ. Educ. Review 109, 110 (2019); Tom Chang et al., *Particulate Pollution and the Productivity of Pear Packers*, 8 Am. Econ. J. Econ. Policy 141, 142 (2016); Tom Y. Chang et al., *The Effect of Pollution on Worker Productivity: Evidence From Call Center Workers in China*, 11 Am. Econ. J. Applied Econ. 151, 152 (2019); Janet Currie & Matthew Neidell, *Air Pollution and Infant Health: What Can We Learn from California's Recent Experience?* 120 Q. J. Econ. 1003, 1004 (2005); Janet Currie, Matthew Neidell & Johannes F. Schmieder, *Air Pollution and Infant Health: Lessons from New Jersey*, 28 J. Health Econ. 688, 688 (2009); Janet Currie & Reed Walker, *Traffic Congestion and Infant Health: Evidence from E-ZPass*, 3 Am. Econ. J. Applied Econ. 65, 65 (2011); Christopher R. Knittel, Douglas L. Miller & Nicholas J. Sanders, *Caution, Drivers! Children Present: Traffic, Pollution, and Infant Health.* 98 Rev. Econ. Stat. 350, 350 (2016); Emilia Simeonova et al., *Congestion Pricing, Air Pollution and Children's Health* 2 (Nat'l Bureau of Econ. Research, Working Paper No. 24410, 2018).

[43] *See*, U.S. Envtl. Protection Agency, Final Rule for Control of Air Pollution from Motor Vehicles: Tier 3 Motor Vehicle Emission and Fuel Standards, https://www.epa.gov/regulations-emissions-vehicles-and-engines/final-rule-control-air-pollution-motor-vehicles-tier-3.

[44] *See* Joshua Linn, *Interactions Between Climate and Local Air Pollution Policies: The Case of European Passenger Cars*, 6 J. Ass'n Envtl. Res. Economists 709, 710 (2019).

[45] Some major metropolitan areas, and the state of California, use reformulated gasoline or oxygenated blends that is intended to improve air quality as part of compliance with the Clean Air Act amendments. Except in the state of California, these policies have had mixed results. *See* Maximilian Auffhammer & Ryan Kellogg, *Clearing the Air? The Effects of Gasoline Content Regulation on Air Quality*, 101 Am. Econ. Review 2687, 2688 (2011).

[46] Standards for new vehicles began to be introduced in California and the federal government followed with provisions in the Clean Air Act. Under the Clean Air Act, the standards have been introduced in tiers, the most recent of which is Tier III. *See* U.S. Envtl. Protection Agency, Timeline of Major Accomplishments in Transportation, Air Pollution, and Climate Change, https://www.epa.gov/transportation-air-pollution-and-climate-change/timeline-major-accomplishments-transportation-air (last updated January 10, 2017); U.S. Envtl. Protection Agency, Light Duty Vehicle Emissions, https://www.epa.gov/greenvehicles/light-duty-vehicle-emissions (last updated September 24, 2019).

[47] U.S. Envtl. Protection Agency, *supra* note 6.

[48] *See* Jeremy Johnson, Doh-Won Lee, Reza Farzaneh, Josias Zietsman & Lei Yu, Tex. Transp. Institute, Report No. FHWA/TX-12/0-6237-1, C*haracterization of Exhaust Emissions from Heavy-Duty Diesel Vehicles in the HGB Area 51* (2011).

[49] *See generally* Yawen Guan et al., *Fine-Scale Spatiotemporal Air Pollution Analysis Using Mobile Monitors on Google Street View Vehicles*, 0 J. Am. Statistical Ass'n 1 (2019).

[50] *See* Univ. of Mich. Ctr. for Sustainable Sys., U.S. Cities Factsheet (2019), http://css.umich.edu/factsheets/us-cities-factsheet.

[51] *See* Jeffrey Shrader, Burcin Unel, & Avi Zevin. Inst. for Policy Integrity, *Valuing Pollution Reductions* (2018).

[52] *See* Karen Clay, Akshaya Jha, N.Z. Muller, & Randy Walsh, *The External Costs of Shipping Petroleum Products by Pipeline and Rail: Evidence of Shipments of Crude Oil from North Dakota*, 40 Energy J. 55, 62 (2019) (describing the AP2 and AP3 model).

[53] *See* Parry et al., *supra* note 3, at 379; *see also* Kenneth A. Small, Erik T. Verhoef, & Robin Lindsey, *The Economics of Urban Transportation* 45 (2007).

[54] VMT in January 1982 was 109,757 million miles. Thirty-five years later, in January of 2017 VMT was 242,600 million miles. *See* U.S. Dep't of Transp., Fed. Highway Admin., Travel Monitoring: Historical Monthly VMT Report, https://www.fhwa.dot.gov/policyinformation/travel_monitoring/historicvmt.cfm (last modified Nov. 26, 2019). For comparison, the U.S. population grew only 40% during the same time. *See* World Bank, Population, Total for United States, https://fred.stlouisfed.org/series/POPTOTUSA647NWDB, July 29, 2020 (last visited July 30, 2020).

[55] *See* Jun Yang, Avralt-Od Purevjav, & Shanjun Li, *The Marginal Cost of Traffic Congestion and Road Pricing: Evidence from a Natural Experiment in Beijing*, 12 Am. Econ. J. Econ. Policy 418 (2020); *see also* Daniel Mangrum & Alejandro Molnar, *The Marginal Congestion of a Taxi in New York City* (2017), Working Paper, https://www.danielmangrum.com/docs/Boro_current.pdf.

[56] *See* Small et al., *supra* note 53, at 53; I. I. Waters & G. William, *Values of Travel Time Savings in Road Transport Project Evaluation, Volume 3: Transport Policy, reprinted in* David A. Hensher, Jenny King, & Tae Hoon Oum, *World Transport Research: Proceedings of the 7th World Conference on Transport Research* (1996) (providing meta analysis).

[57] *See* Michael L. Anderson, *Subways, Strikes, and Slowdowns: The Impacts of Public Transit on Traffic Congestion*, 104 Am. Econ. Review 2763, 2767 (2014); Small et al., *supra* note 53, at 54.

[58] *See* U.S. Dep't of Transp., *The Value of Travel Time Savings: Departmental Guidance for Conducting Economic Evaluations Revision 2 (2016 Update)* (2016), at 13, https://www.transportation.gov/sites/dot.gov/files/docs/2016%20Revised%20Value%20of%20Travel%20Time%20Guidance.pdf.

[59] *See* U.S. Dep't of Transp., *supra* note 9, at 2.

[60] *See generally* Issi Romem & Ity Shurtz, *The Accident Externality of Driving: Evidence From Observance of the Jewish Sabbath in Israel*, 96 J. Urban Econ. 36 (2016).

[61] *See* AAA, Liability Laws: United States, https://drivinglaws.aaa.com/tag/liability-laws/ (last visited June 20, 2020) (listing liability laws by state).

[62] For example, insurance policies that differentiate by miles traveled or vehicle weight are better at internalizing the risk to others than policies that are not differentiated whatsoever.

[63] *See* U.S. Dep't of Transp., Nat'l Highway Traffic Safety Admin., The Economic and Societal Impact Of Motor Vehicle Crashes, 2010 (Revised) (2015), https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812013.

[64] *Id.*

[65] Arthur Van Benthem, *What is the Optimal Speed Limit on Freeways?*, 124 J. Pub. Econ. 44, 45 (2015).

[66] *See*, Michael L. Anderson & Maximilian Auffhammer, *Pounds That Kill: The External Costs of Vehicle Weight*, 81 Rev. Econ. Stud. 535, 535 (2013). The effect of vehicle weight is more nuanced, however. It is the difference in vehicle weight between the two vehicles in the crash that best determines total harm from traffic collisions. *See* Antonio Bento, Kenneth Gillingham, & Kevin Roth, *The Effect of Fuel Economy Standards on Vehicle Weight Dispersion and Accident Fatalities* (Nat'l Bureau of Econ. Research, Working Paper No. 23340, 2017). This leads to an additional market failure, a failure in coordination where a "vehicle-arms race" incentivizes everyone to buy heavier vehicles. Like the classic case of the prisoner's dilemma, the equilibrium outcome makes everyone worse off relative to a cooperative outcome where everyone chooses a lighter weight vehicle (or regulation results in a decrease in vehicle weight fleetwide). *See* Michelle J. White, *The "Arms Race"On American Roads: The Effect of Sport Utility Vehicles and Pickup Trucks on Traffic Safety*, 47 J. L. Econ. 333, 333 (2004). This relationship between vehicle weight and safety is complicated further, as recent research suggests that modern manufacturing materials and techniques allow automakers to decrease vehicle weight and maintain, or even increase, vehicle safety with minimal increases in vehicle production costs. *See* Gregory Peterson, Consumers Union, Report No. CU-MMTC-Safety-Study-10-24-2018, *Review of Safety of Reduced Weight Passenger Cars and Light Duty Trucks* 2 (2018), https://www.regulations.gov/contentStreamer?documentId=EPA-HQ-OAR-2018-0283-7673&attachmentNumber=22&contentType=pdf. *See*, Inst. For Policy Integrity, *supra* note 27 at 125-127.

[67] *See, e.g.,* U.S. Envtl. Protection Agency, Cost of Illness Handbook (2002), https://nepis.epa.gov/Exe/ZyPDF.cgi/901A0E00.PDF?Dockey=901A0E00.PDF; *see also* U.S. Dep't of Transp., Nat'l Highway Traffic Safety Admin., *supra* note 9.

[68] Richard L. Revesz & Michael A. Livermore, *Retaking Rationality: How Cost-Benefit Analysis Can Better Protect the Environment and Our Health* 47 (2008).

[69] *See* U.S. Envtl. Protection Agency, Guidelines for Preparing Economic Analyses: Mortality Risk Valuation Estimates, Appendix B (2010), https://www.epa.gov/sites/production/files/2017-09/documents/ee-0568-22.pdf (showing $7.4 million in 2006 dollars inflated to 2020); *see also* Dep't of Transp., Memorandum on Guidance of Treatment of the Economic Value of a Statistical Life (Aug. 8, 2016), https://www.transportation.gov/sites/dot.gov/files/docs/2016%20Revised%20Value%20of%20a%20Statistical%20Life%20Guidance.pdf.

[70] *See* Davis Noll et al., *supra* note 21 at 17.

[71] *See* Gloria Helfand & Ann Wolverton, *Evaluating the Consumer Response to Fuel Economy: A Review of Literature*, 5 Int'l Rev. Envtl. & Resource Econ. 103, 128-30 (2011); Todd D. Gerarden et al., *Assessing the Energy-Efficiency Gap*, 55 J. Econ. Lit. 1486, 1487-88 (2017).

[72] James Sallee, *Rational Inattention and Energy Efficiency*, 57 J. Law & Econ. 781, 782-85 (2014).

[73] David L. Greene, *Consumers' Willingness to Pay for Fuel Economy and Implications for Sales of New Vehicles and Scrappage of Used Vehicles*, Environmental Defense Fund 5 (Oct. 21, 2018), https://www.edf.org/sites/default/files/CARB_Report_Greene_UTenn_Consumer_Behavior_Modeling.pdf (describing behavioral economic explanations for the fuel efficiency paradox, including loss aversion).

[74] Gloria Helfand & Reid Dorsey-Palmateer, *The Energy Efficiency Gap in EPA's Benefit-Cost Analysis of Vehicle Greenhouse Gas Regulations: A Case Study*, 6 J. Benefit Cost Anal. 432, 439 (2015).

[75] *See generally* Todd D. Gerarden, Richard G. Newell, & Robert N. Stavins, *Assessing the Energy-Efficiency Gap*, 55 J. Econ. Literature 1486 (2017).

[76] Carolyn Fischer, *Imperfect Competition, Consumer Behavior, and the Provision of Fuel Efficiency in Light-Duty Vehicles* 4 (Res. for the Future, Discussion Paper No. DP 10-60, 2010), https://media.rff.org/documents/RFF-DP-10-60.pdf. Conversely, if consumers over-value fuel savings, market power allows auto manufacturers to over-provide fuel efficient vehicles. This is unlikely to be the case however, as consumers typically undervalue fuel efficient vehicles. *See* Davis Noll et al., *supra* note 21.

[77] U.S. Envtl. Protection Agency, Regulatory Impact Analysis for Final Rulemaking to Establish Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards 8-10 (Apr. 2010), https://nepis.epa.gov/Exe/ZyPDF.cgi/P1006V2V.PDF?Dockey=P1006V2V.PDF.

[78] Nat'l Rsch. Council, Cost, Effectiveness, and Deployment of Fuel Economy Technologies for Light-Duty Vehicles 319 (2015), http://nap.edu/21744 (explaining that manufacturers may face a first-mover disadvantage for developing new fuel-efficiency technologies, and regulation can help overcome that perceived disadvantage as well as bring down costs through economies of scale and learning, and thus may "lead to a more optimal provision of fuel economy in the marketplace").

[79] *See* Kenneth Gillingham & James Sweeney, *Market Failure and the Structure of Externalities, in Harnessing Renewable Energy in Electric Power Systems* 77 (Boaz Moselle, Jorge Padilla, & Richard Schmalensee eds., 2010).

[80] *See generally* Katalin Springel, *Network Externality and Subsidy Structure in Two-Sided Markets: Evidence from Electric Vehicle Incentives* (2016), http://econweb.umd.edu/~sweeting/kspringel_ev.pdf.

[81] *See* Mankiw, *supra* note 16, at 219.

[82] *See* Robert S. Kirk & William J. Mallett, Cong. Rsch. Serv., R45350, Funding and Financing Highways and Public Transportation 1 (May 2020), https://fas.org/sgp/crs/misc/R45350.pdf.

[83] Economically optimal in the sense that they are the "first-best" policies given the constraints preventing an economy-wide tax on the externality. Any that policy cannot achieve the first best outcome because of a policy constraint however is designed to maximize society's welfare subject to that policy constraint is considered the "second-best" policy. *See generally* Richard G. Lipsey & Kelvin Lancaster, *The General Theory of Second Best*, 24 Rev. Econ. studies 11 (1956).

[84] *See generally* Richard L. Revesz, *Regulation and Distribution*, 93 N.Y.U. L. Rev. 1489 (2018) (describing the rational of equity-based regulations, and the role of the administrative state).

[85] *See generally* Antonio M. Bento et al., *Distributional and Efficiency Impacts of Increased US Gasoline Taxes*, 99 Am. Econ. Rev. 667 (2009) (discussing the importance of how tax revenues are used in determining the distributional impacts of a gas tax and showing that a lump sum return of gasoline tax revenue on a per capita basis would make the bottom four income deciles better off, without accounting for benefits of reduced pollution.).

[86] For a fuel fee to be economically optimal, policies must address the incomplete valuation of future fuel savings (the "energy-efficiency gap") by ensuring consumers to respond to future fuel prices. This can be accomplished by requiring improvements in fuel economy and better informing consumers of future fuel savings.

[87] This doesn't apply to electricity as a transportation fuel. So long as there is a policy to address those GHG emissions, there's no reason to address them again in the transportation sector. Because stationary sources, like electricity generators, are easier to regulate than mobile ones, like transportation, this is more likely than not. *See* Meredith Fowlie, Christopher R. Knittel, & Catherine Wolfram, *Sacred Cars? Cost-effective Regulation of Stationary and Non-stationary Pollution Sources*, 4 Am. Econ. J. Econ. Policy 98, 100 (2012).

[88] *See* Shanjun Li, Christopher Timmins, & Roger H. Von Haefen, H*ow Do Gasoline Prices Affect Fleet Fuel Economy?* 1 Am. Econ. J. Econ. Policy 113, 115 (2009); Soren T. Anderson & James M. Sallee, *Designing Policies to Make Cars Greener: A Review of the Literature*, 8 Ann. Rev. Res. Econ. 157, 162 (2016).

[89] This was calculated using the IWG's estimates of the Social Cost of Carbon IWG. *See* Revesz et al., *supra* note 34. As that estimate is updated to better reflect the true cost of climate damages, see *supra* note 35 and accompanying text, this fee must be updated as well.

[90] The change in gasoline consumption is based off a gasoline price of $2.00 to $2.50.

[91] Estimates for the price elasticity of gasoline vary, but recent estimates put it between -0.03 and -0.07. *See* Jonathan Hughes, Christopher R. Knittel & Daniel Sperling, *Evidence of a Shift in the Short-Run Price Elasticity of Gasoline Demand*, 29 Energy J. 113, 115 (2008).

[92] *See* Shanjun Li, Joshua Linn, & Erich Muehlegger, *Gasoline Taxes and Consumer Behavior*, 6 Am. Econ. J. Econ. Policy 302 (2014); Julius J. Andersson, *Carbon Taxes and CO_2 Emissions: Sweden as a Case Study*, 11 Am. Econ. J. Econ. Policy 1, 1 (2019) (showing a carbon tax elasticity is 3 times greater than price elasticity); Nicholas Rivers & Brandon Schaufele, *Salience of Carbon Taxes in the Gasoline Market*, 74 J. Envtl. Econ. Mgmt. 23, 31 (2015); Lucas

W. Davis & Lutz Kilian, *Estimating the Effect of a Gasoline Tax on Carbon Emissions* 26 J. App. Econ. 1187 (2011).

93 *See, e.g.,* Shanjun Li, Joshua Linn, & Erich Muehlegger, *Gasoline Taxes and Consumer Behavior*, 6 Am. Econ. J. Econ. Policy 302, 304 (2014) (showing a 5-cent increase in the price of gasoline decreases gasoline consumption by 0.86 percent. Extrapolating this to a 50-cent tax, this result suggests an 8.6 percent decrease in consumption.).

94 Lucas W. Davis & James M. Sallee, *Should Electric Vehicle Drivers Pay a Mileage Tax?*, in 1 Environmental and Energy Policy and the Economy 65 (Matthew J. Kotchen, James H. Stock, & Catherine D. Wolfram eds., 2020).

95 *See* Lucy Davis & James Sallee, Should Electric Drivers Pay a Mileage Tax?, Energy Inst. Blog (Apr. 8, 2019), https://energyathaas.wordpress.com/2019/04/08/should-electric-vehicle-drivers-pay-a-mileage-tax/ ("California, Washington, and Illinois have all conducted mileage tax pilots, and Oregon passed legislation allowing 5,000 voluntary motorists to pay a mileage tax of 1.7 cents per mile, in lieu of gasoline taxes.").

96 *See* Lucas W. Davis & James M. Sallee, *Should Electric Vehicle Drivers Pay a Mileage Tax?*, in 1 Environmental and Energy Policy and the Economy 65, 71 (Matthew J. Kotchen, James H. Stock, & Catherine D. Wolfram eds., 2020).

97 *See, e.g.,* Michael L. Anderson, *supra* note 57, 2764 (using transit worker strikes in Los Angeles to show the benefits of public transportation infrastructure are much larger than previously believed); *see also* Christopher D. Porter et al., U.S. Dep't of Energy, Office of Sci. and Tech. Info., Technical Report No. DOE/GO-102013-3703, *Effects of the Built Environment on Transportation: Energy Use, Greenhouse Gas Emissions, and Other Factors* 1 (2013) (showing changes in the built environment could reduce transportation GHG emissions by up to 10% by 2050).

98 *See* CleanTechnica, *The EV Safety Advantage* 2 (2018) ("[F]ully electric cars score highly in independent safety tests. The Chevrolet Volt has the lowest personal injury claims of small, four-door cars, and is 29% better than the average car in that category.").

99 42 U.S.C. § 7521(a) (2018).

100 *See* Endangerment and Cause or Contribute Findings for Greenhouse Gases, 74 Fed. Reg. 66,496 (Dec. 15, 2009).

101 *See* 2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards, 77 Fed. Reg. 62,624 (Oct. 15, 2012) [hereinafter Clean Car Standards].

102 *Coal. for Responsible Regulation, Inc. v. EPA*, 684 F.3d 102, 122 (D.C. Cir. 2012), *aff'd in part, rev'd in part sub nom. Util. Air Regulatory Grp. v. EPA*, 134 S. Ct. 2427 (2014).

103 Clean Car Standards, *supra* note 101; Nat'l Highway Traffic Safety Admin., Fact Sheet 1, 4 (2012), https://www.nhtsa.gov/staticfiles/rulemaking/pdf/cafe/CAFE 2017-25 Fact Sheet.pdf (reporting that NHTSA's standards would reach a combined fleet-wide average of 48.7-49.7 mpg, while EPA's—if achieved all through fuel economy improvements and not air conditioning improvements— would hit 54.5 mpg by 2025, with an overall rate of improvement of about 4.7-4.9%). NHTSA set final standards for model years 2017 to 2021 and non-final "augural" standards for model years 2022 to 2025, meaning that those standards represented the agency's "best estimate" of the appropriate level of stringency for those model years, based on the information available in 2012; 2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards, 77 Fed. Reg. 62,624, 62,627 (Oct. 15, 2012).

104 77 Fed. Reg. 62,624, 62,652, 63,161(Oct. 15, 2012).

105 2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards, 76 Fed. Reg. 74,854, 74,861 (Dec. 1, 2011) (proposing midterm evaluation); *see also* 77 Fed. Reg. at 62,652 (adopting proposal).

106 *See* U.S. Envtl. Prot. Agency, Final Determination on the Appropriateness of the Model Year 2022-2025 Light-Duty Vehicle Greenhouse Gas Emissions Standards under the Midterm Evaluation (2017) [hereinafter 2017 Final Determination], *available at* https://www.govinfo.gov/content/pkg/FR-2018-04-13/pdf/2018-07364.pdf; *see also* U.S. Envtl. Prot. Agency, Draft Technical Assessment Report: Midterm Evaluation of Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards for Model Years 2022-2025 (2016) [hereinafter Draft TAR 2016], available at https://www.nhtsa.gov/staticfiles/rulemaking/pdf/cafe/Draft-TAR-Final.pdf.

107 2017 Final Determination, *supra* note 106 at 30. In April 2018, EPA reversed course and withdrew the Final Determination concluding that the standards were "not appropriate." But that conclusion was not supported by the evidence. *See* Bethany Davis Noll, Peter Howard & Jeffrey Shrader, Inst. for Policy Integrity, *Analyzing EPA's Vehicle-Emissions Decisions: Why Withdrawing the 2022-2025 Standards Is Economically Flawed* (2018), https://policyintegrity.org/files/publications/Analyzing_EPAs_Fuel-Efficiency_Decisions_Policy_Brief.pdf. In litigation over that withdrawal, the U.S. Court of Appeals for the D.C. Circuit made clear that EPA must consider the evidence developed for the Midterm Evaluation in any final rule changing the standards. *California v. EPA*, 940 F.3d 1342, 1351 (D.C. Cir. 2019).

108 Benjamin Leard, Joshua Linn, & Katalin Springel, *Have US Fuel Economy and Greenhousle Gas Emissions Standards Improved Social Welfare?* 1 (Resources for the Future, Working Paper No. 20-06, 2020).

109 The Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Model Years 2021-2026 Passenger Cars and Light Trucks, 85 Fed. Reg. 24,174 (Apr. 30, 2020).

[110] 49 U.S.C. 32902(a)(3)(A) (2018); Clean Car Standards, *supra* note 101, at 62,686 ("EPCA, as amended by EISA, expressly requires that CAFE standards for passenger cars and light trucks be based on one or more vehicle attributes related to fuel economy, and be expressed in the form of a mathematical function.").

[111] *Id.* ("The CAA has no such requirement").

[112] *See* Insurance Institute for Highway Safety Inst, *Comments Re: Notice of Proposed Rulemaking; 49 CFR Parts 523, 531, 533, 534, 536, and 537; Average Fuel Economy Standards, Passenger Cars and Light Trucks, Model Years 2011-2015; Docket No. NHTSA-2008-0089* at 2 (June 27, 2008).

[113] *See*, Inst. For Policy Integrity, *supra* note 27 at 125-127 (discussing the weak statistical evidence relating vehicle weight and safety.)

[114] *See* Kate S. Whitefoot & Steven J. Skerlos, *Design Incentives to Increase Vehicle Size Created From the US Footprint-Based Fuel Economy Standards*, 41 Energy Pol'y 402, 402 (2012); Koichiro Ito & James M. Sallee, *The Economics of Attribute-Based Regulation: Theory and Evidence from Fuel Economy Standards*, 100 Rev. Econ. Stat. 319, 319 (2018) (noting that attribute-based regulations are generally inefficient).

[115] *See* Anderson & Auffhammer *supra* note 66; Antonio Bento, Kenneth Gillingham, & Kevin Roth, *The Effect of Fuel Economy Standards on Vehicle Weight Dispersion and Accident Fatalities* (Nat'l Bureau of Econ. Research, Working Paper No. 23340, 2017); Justin Tyndall, *Pedestrian Deaths and Large Vehicles*, Working Paper (2020), https://www.justintyndall.com/uploads/2/8/5/5/28559839/tyndall_pedestrian.pdf.

[116] *See generally* Whitefoot & Skerlos, *supra* note 114; Koichiro Ito & James M. Sallee, *supra* note 114; Ryan Kellogg, *Gasoline Price Uncertainty and the Design of Fuel Economy Standards*, 160 J. Pub. Econ. 114 (2018); Ryan Kellog, *Output and Attribute-Based Carbon Regulation Under Uncertainty* (Nat'l Bureau of Econ. Research, Working Paper No. 26172, 2019).

[117] Ito & Sallee, *supra* note 114, at 319-20 ("In brief, we conclude that it is unlikely that attribute basing is justified on efficiency grounds . . . [attribute-based regulations] *can contribute to efficiency by equalizing the marginal costs of regulatory compliance across sources in certain settings.* Some policies (including [corporate average fuel economy]) have a compliance trading system, which means that *the market as a whole must meet the standard on average and the market for compliance credits will equalize marginal costs of compliance.*") (emphasis added).

[118] The economic literature provides two other justifications for implementing an attribute-based standard. First, attribute-based standards can play a role in achieving distributional goals. *Id.* at 320. Although perhaps important from a political perspective, the political benefits should be weighed against the real economic costs. *Id.* ("size-based fuel economy regulations can be rationalized as a way of shifting welfare between firms that sell small vehicles and those that sell large vehicles (perhaps in order to favor domestic producers and their consumers).") Alternatively, the role of fuel price uncertainty can potentially justify attribute-based standards, as an unanticipated reduction in the price of fuel can increase the demand for fuel-inefficient vehicle provided by an attribute-based standard. Kellogg (2018), *supra* note 112. This alone does not justify attribute-basing. Kellogg 2018, *supra* note 116, at 15 ("even if fuel prices are uncertain, attribute-basing reduces expected welfare relative to an optimally-set non-attribute-based standard, since the distortions caused to the attribute and to fuel economy outweigh the flexibility benefit."); Kellogg (2019), *supra* note 116, at 1 ("For fuel economy standards, the welfare-maximizing amount of attribute or mileage-basing is likely small relative to current policy.").

[119] *See* 40 C.F.R. § 86.1865-12(k) (2020).

[120] *See* Jason A. Schwartz, Admin. Conf. of the U.S., Final Report on Marketable Permits: Recommendations on Applications and Management 86-87 (Dec. 11, 2017), https://www.acus.gov/sites/default/files/documents/Marketable%20Permits%20Report-final.pdf.

[121] The Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule, 85 Fed. Reg. at 25,220.

[122] *See* Michael Greenstone, Cass Sunstein & Sam Ori, *The Next Generation of Transportation Policy* (The Hamilton Project and Energy Policy Institute at University of Chicago, Policy Proposal No. 2017-02, 2017).

[123] *Id.* at 17, 23.

[124] *Id.* at 6 ("For example, the typical Honda Civic being retired today has been driven 169,000 miles over its lifetime, whereas the average Mitsubishi Mirage has been driven 92,000 miles. The models have nearly identical fuel efficiency, but vastly different lifetime fuel consumption.").

[125] *See supra* note 114.

[126] *See* Bentley Clinton & Daniel Steinberg, *Providing the Spark: Impact of Financial Incentives on Battery Electric Vehicle Adoption?*, 98 J. Env. Econ. Mgmt. (2019).

[127] Paul A. Eisenstein, *AAA Study Finds Americans Are Warming to Electric Vehicles, But Most Aren't Ready to Buy – At Least Not Yet*, CNBC (May 9, 2019), https://www.cnbc.com/2019/05/08/aaa-says-americans-warm-to-electric-cars-but-most-arent-ready-to-buy.html.

[128] *See* MIT Energy Initiative, *Insights into Future Mobility* xvi (2019), http://energy.mit.edu/publication/insights-into-future-mobility/ (discussing cost parity in the United States near 2030). *See also* Bloomberg New Energy Finance, *Electric Vehicle Outlook 2020* 3.1 (2020), https://about.bnef.com/electric-vehicle-outlook/ (showing a wide variation of estimated cost parity by vehicle segment, from 2022 to 2030).

[129] The environmental benefits of increased electric vehicle adoption do not outweigh the cost of purchase subsidies in 2010 (except in California and Texas). Clinton and Steinberg, *supra* note 126. Since then, however, the transition to more wind and solar, and less coal, to generate electricity changes this accounting. Electric vehicle adoption provides more benefits than costs in the western United States and nearly all major cities in the eastern United States. *See* Holland et al., *supra* note 32, at 10. This suggests some purchase subsidy is justified based on environmental benefits alone. There are additional, strictly positive, benefits of electric vehicle adoption including network externalities and increased production efficiencies because of economies of scale or accelerated innovation in the supply chain. Clinton & Steinberg, *supra* note 126, at 16. Collective, these additional benefits suggest electric vehicle purchase subsides provide benefits that outweigh their costs.

[130] *See* Molly F. Sherlock, Cong. Rsch. Serv., IF11017, The Plug-In Electric Vehicle Tax Credit 1 (2019), https://fas.org/sgp/crs/misc/IF11017.pdf.

[131] *See, e.g.,* U.S. Dep't of Energy, Federal Tax Credits for New All-Electric and Plug-In Hybrid Vehicles, https://www.fueleconomy.gov/feg/taxevb.shtml (last visited June 30, 2020).

[132] *See* Clinton & Steinberg, *supra* note 126 (showing the benefits of a direct purchase rebate in comparison to an income tax credit).

[133] Jianwei Xing, Benjamin Leard, & Shanjun Li, *What Does an Electric Vehicle Replace?* 3 (Nat'l Bureau of Economic Research, Working Paper No. 25771, 2019).

[134] *See* Burak Sen, Mehdi Noori, & Omer Tatari, *Will Corporate Average Fuel Economy (CAFE) Standard Help? Modeling CAFE's Impact on Market Share of Electric Vehicles*, 109 Energy Policy 279 (2017).

[135] Hart Schwartz, *America's Aging Vehicles Delay Rate of Fleet Turnover*, The Fuse (Jan. 23, 2019), http://energyfuse.org/americas-aging-vehicles-delay-rate-fleet-turnover/.

[136] 42 U.S.C. § 7521.

[137] *See* Jonathan Nash & Richard L. Revesz, *Grandfathering and Environmental Regulation: The Law and Economics of New Source Review*, 101 N. W. L. Rev. 1677 (2007).

[138] *See* Howard K. Gruenspecht, *Differentiated Regulation: The Case of Auto Emissions Standards*, 72 Am. Econ. Rev. 328, 328 (1982).

[139] *See* Meghan R. Busse et al., MIT Ctr. for Energy and Envtl. Policy Research, *Did "Cash for Clunkers" Deliver? The Consumer Effects of the Car Allowance Rebate System* 1 (2012), http://ceepr.mit.edu/files/papers/2013-009.pdf.

[140] *Id.*at 3.

[141] *See also* Shanjun Li, Joshua Linn & Elisheba Spiller, *Evaluating "Cash-for-Clunkers": Program effects on auto sales and the environment*, 65 J. Envtl. Econ. mgmt. 175, 176 (2013) (showing a cost per ton of GHG abated ranging from $92 to $288 (including co-benefits)).

[142] Mark Hoekstra, Steven L. Puller, & Jeremy West, *Cash for Corollas: When Stimulus Reduces Spending*, 9 Am. Econ. J. Applied Econ. 1, 2, 3 (2017).

[143] *See generally* Lucas W. Davis & Matthew E. Kahn, *Cash for Clunkers? The Environmental Impact of Mexico's Demands for Used Vehicles*, 38 ACCESS Magazine 15 (2011).

[144] Cost parity between internal combustion engines and electric vehicles ultimately depend on the decreasing costs of batteries. In the U.S., this is likely to happen sometime between 2022 and 2030. *See* MIT Energy Initiative, *supra* note 128, at 16. *See also*, Bloomberg New Energy Finance, *supra* note 128.

[145] E.g., the "yellow-vest" movement in France in October of 2018 in opposition to rising fuel prices.

[146] *See generally* Daniel Sperling & Sonia Yeh, *Toward a Global Low Carbon Fuel Standard*, 17 Transp. Pol'y 47 (2010).

[147] *See* Cal. Air Res. Bd., Low Carbon Fuel Standard, https://ww2.arb.ca.gov/our-work/programs/low-carbon-fuel-standard (last visited June 30, 2020); *see also* Or. Dep't of Envtl. Quality, Clean Fuels Program Regulations: Clean Fuel Standards, https://www.oregon.gov/deq/aq/programs/Pages/Clean-Fuels-Regulations.aspx (last visited June 30, 2020).

[148] *See* Leigh Noda, Stillwater Assoc., The LCFS Cost in Transportation Fuels – The Growing Hidden Tax (June 7, 2017), https://stillwaterassociates.com/lcfs-cost-fuels-growing-hidden-tax/.

[149] For example, hydrogen powered vehicles are possible with limited to no carbon emissions, however, the technology is not readily deployable right now.

[150] Ryan Kellogg (2019) *supra* note 116.

[151] Fortunately, policy mechanisms can be designed to stabilize the permit price, and so, stabilize the compliance costs. Generally, these mechanisms tighten the cap if the permit price is too low or loosens the cap when permit prices are too high. *See, e.g.,* H. Fell, D. Burtraw, R.D. Morgenstern, & K. L. Palmer, *Soft and Hard Price Collars in a Cap-And-Trade System: A Comparative Analysis*, 64 J. Envtl. Econ. Mgmt. 183, 183 (2012).

[152] 42 U.S.C. § 7545(c)(1) (2018).

[153] *Id.* § 7545(c)(2)(A).

[154] *Union Oil Co. of California v. EPA*, 821 F.2d 678 (D.C. Cir. 1987).

[155] *See* Control of Air Pollution From New Motor Vehicles: Tier 2 Motor Vehicle Emissions Standards and Gasoline Sulfur Control Requirements, 65 Fed. Reg. 6698, 6765 (Feb. 10, 2000).

[156] *See* Jack Lienke & Jason A Schwartz, Inst. for Policy Integrity, *Shifting Gears: A new Approach to Reducing Greenhouse Gas Emissions from the Transportation Sector* 7 (2014), https://policyintegrity.org/files/publications/Shifting_Gears.pdf (explaining EPA has authority to implement a mass-based credit-trading program for vehicle fuels under section 211 of the Clean Air Act).

[157] U.S. Energy Info. Admin., Frequently Asked Questions (FAQs): How Much Tax Do We Pay on a Gallon of Gasoline and on a Gallon of Diesel Fuel, https://www.eia.gov/tools/faqs/faq.php?id=10&t=10 (last updated February 27, 2020).

[158] David Schaper, *It's Been 25 Years Since the Federal Gas Tax Went Up*, NPR (Oct. 5, 2018), https://www.npr.org/2018/10/05/654670146/its-been-25-years-since-the-federal-gas-tax-went-up.

[159] *See* Kirk & Mallett *supra* note 82.

[160] In addition to a general decline in the demand for gasoline since March, disagreements amongst the Organization of the Petroleum Exporting Countries (OPEC) members around the same time lead to a glut of petroleum being supplied to the United States. In the interim, OPEC members have largely resolved their dispute while demand for gasoline has remained laggard. *See* Natasha Turak, *OPEC+ Mostly Met Its Cutting Targets in May, But Future Compliance – And Its Enforcement – Looks Uncertain*, CNBC (June 11, 2020), https://www.cnbc.com/2020/06/11/opec-mostly-met-cut-targets-in-may-but-future-compliance-uncertain.html; U.S. Energy Info. Admin., This Week in Petroleum, https://www.eia.gov/petroleum/weekly/gasoline.php#tabs-gasoline-demand-finished (last updated July 22, 2020).

[161] *See generally* Ashley Langer, Vikram Maheshri, & Clifford Winston, *From Gallons to Miles: A Disaggregate Analysis of Automobile Travel and Externality Taxes*, 152 J. Pub. Econ. 34 (2017).

[162] *See* News Release, Or. Dep't of Transp., Some Oregon Vehicle Fees Will Be Based on MPG Starting in 2020 (Nov. 12, 2019), https://content.govdelivery.com/accounts/ORDOT/bulletins/26b9b62.

[163] A review of existing vehicle registration fee programs, as compiled by the National Conference of State Legislatures, suggests that such fees are typically set directly by the legislature rather than a state agency acting pursuant to delegated authority. *See* Nat'l Conference of State Legislators, Vehicle Registration Fees by State (Feb. 4, 2020), https://www.ncsl.org/research/transportation/registration-and-title-fees-by-state.aspx.

[164] Participants in 2010 included Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont. *See* Transportation & Climate Initiative of the Northeast and Mid-Atlantic States, An Agenda For Progress 3-5 (2010), https://www.transportationandclimate.org/sites/default/files/TCI-declaration.pdf.

[165] Draft Memorandum of Understanding of the Transportation and Climate Initiative (Dec. 17, 2019), https://perma.cc/TD6K-SNN5; Webinar: Draft Memorandum of Understanding & 2019 Cap-and-Invest Modeling Results, Transp. And Climate Initiative (Powerpoint Presentation, Dec. 17, 2019), https://www.transportationandclimate.org/sites/default/files/TCI%20Public%20Webinar%20Slides_20191217.pdf.

[166] U.S. Dep't. of Transp., *supra* note 10.

[167] *See, e.g.,* Fixing America's Surface Transportation (FAST) Act, Pub. L. No. 114-94, 129 Stat. 1314 (2015).

[168] Robert S. Kirk, Cong. Rsch. Serv., R45727, The Highway Funding Formula: History and Current Status 1 (2019), https://fas.org/sgp/crs/misc/R45727.pdf.

[169] U.S. Dep't of Transp., Fed. Highway Admin., Federal-Aid Highway Program Authorizations Under The Fixing America's Surface Transportation (FAST) Act, https://www.fhwa.dot.gov/fastact/estfy20162020auth.pdf (last accessed July 1, 2020).

[170] 23 U.S.C. §§ 119 (e)(5) ("[E]ach fiscal year, if the Secretary determines that a State has not developed and implemented a State asset management plan consistent with this section, the Federal share payable on account of any project or activity for which funds are obligated by the State in that fiscal year under this section shall be 65 percent."). The typical federal share is 80-95%. Transp. for Am., The National Highway Performance Program, http://t4america.org/wp-content/uploads/2012/11/MAP-21-Explainer-NHPP.pdf (last accessed Apr. 18, 2020).

[171] *See* U.S. Dep't of Transp., National Performance Management Measures; Assessing Performance of the National Highway System, Freight Movement on the Interstate System, and Congestion Mitigation and Air Quality Improvement Program, 82 Fed. Reg. 5970, 5993, 6001 (Jan. 18, 2017) [hereinafter Tailpipe Emissions Rule].

[172] *Id.*

[173] U.S. Dep't of Transp., National Performance Management Measures; Assessing Performance of the National Highway System, Freight Movement on the Interstate System, and Congestion Mitigation and Air Quality Improvement Program, 83 Fed. Reg. 24,920, 24,923 (May 31, 2018).

[174] 82 Fed. Reg. at 5993 (citing 23 U.S.C. § 150(b)(6) ("To enhance the performance of the transportation system while protecting and enhancing the natural environment.")).

[175] *See* U.S. Dep't of Transp., Notice of Funding Opportunity for the Department of Transportation's National Infrastructure Investments under the Consolidated Appropriations Act, 2020, 85 Fed. Reg. 10,811, 10,818 (Feb. 25, 2020).

[176] U.S. Dep't of Transp., Benefit-Cost Analysis Guidance for Discretionary Grant Programs 34 tbl. A-7 (2020), https://www.transportation.gov/sites/dot.gov/files/2020-01/benefit-cost-analysis-guidance-2020_0.pdf.

[177] *See* 85 Fed. Reg. at 10,821.

[178] *See*, Transportation for America, Trump's USDOT BUILDs even more roads (November 2019), http://t4america.org/2019/11/26/trumps-usdot-builds-even-more-roads/.

[179] *See*, AAA, Fact Sheet: Consumer Attitudes – Electric Vehicles (May 2019), https://publicaffairsresources.aaa.biz/download/14035/.

[180] *See generally* Daniel Sperling & Jennifer Dill, *Unleaded Gasoline in the United States: A Successful Model of System Innovation*, 1175 Transp. Rsch. Rec. 45, 45 (1988) ("The transition to unleaded gasoline was unique in that it was instigated and orchestrated by federal rules and laws; market forces did not play a direct or major role."); Richard G. Newell & K. Rogers, *Leaded Gasoline in the United States: The Breakthrough of Permit Trading*, *in* Choosing Environmental Policy: Comparing Instruments and Outcomes in the United States and Europe (Winston Harrington, Richard D. Morgenstern, & Thomas Sterner eds., 2004.

[181] *See, e.g.,* Boyoung Seo & Matthew H. Shapiro, *Cash or Charge: Assessing Charging Station Build Out and Incentive Programs' Roles in Electric Vehicles Adoption* 1 (Working Paper 2015).

[182] 26 U.S.C. §§ 30C, 38 (2018).

[183] Bill Canis, Cong. Rsch. Serv., R45757, Vehicle Electrification: Federal and State Issues Affecting Deployment 5 (2019), https://fas.org/sgp/crs/misc/R45747.pdf; *see also* U.S. Dep't of Energy, Alternative Fuel Infrastructure Tax Credit, https://afdc.energy.gov/laws/10513 (last visited July 1, 2020).

[184] *See* Fixing America's Surface Transportation Act, Pub. L. No. 114-94, 129 Stat. 1413 (2015), https://www.govinfo.gov/content/pkg/PLAW-114publ94/pdf/PLAW-114publ94.pdf.

[185] *See* 23 U.S.C. § 111 (2018); *see also* David Ferris, *EV Chargers at Rest Stops? Not So Fast, Say the Feds,* E&E News (Nov. 27, 2019), https://www.eenews.net/stories/1061656653.

[186] *See* Cong. Budget Office, Report on Public Spending on Transportation and Water Infrastructure, 1956 to 2014, at 8 (Mar. 2, 2015), https://www.cbo.gov/publication/49910.

[187] House Comm. on Transp. And Infrastructure, Fact Sheet for the Invest in America Act, https://transportation.house.gov/imo/media/doc/2020%20INVEST%20In%20America%20Fact%20Sheet.pdf (last visited July 1, 2020).

[188] *See, e.g.,* Smart Growth America, U.S. Dep't of Transp., Fed. Transit Admin., Second Summary Report on Transit-Oriented Development Technical Assistance (Feb. 2018), https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/research-innovation/117636/fta-report-no-0124.pdf.

[189] *See* U.S. Dep't of Transp., Fed. Transit Admin., Pilot Program for Transit-Oriented Development Planning – Section 20005(b), https://www.transit.dot.gov/TOD-Pilot (last visited July 1, 2020) (showing information on the pilot program); Invest in America Act, H.R. Rep. No. 116-437 at 501, Sec. 2701, Sec. 5328 (2020) https://www.congress.gov/bill/116th-congress/house-bill/2/text.

[190] U.S. Dep't of Transp., *supra* note 9.

[191] *See* U.S. Dep't of Transp., Fed. Highway Admin., Publication No. FHWA-RD-03-042A, Review of Pedestrian Safety Research in the United States and Abroad 2-4 (Jan. 2004), https://www.fhwa.dot.gov/publications/research/safety/pedbike/03042/03042.pdf.

[192] John LaPlante & Barbara McCann, *Complete Streets: We Can Get There From Here*, 78 ITE J. 24, 24 (2008).

[193] *See* Invest in America Act, *supra* note 189, Sec. 1107 ("Complete and Context Sensitive Street Design."); *Id.* at Sec. 1601; 23 U.S.C. § 109 (2018); House Comm. on Transp. And Infrastructure, Summary of The "Investing In a New Vision for the Environment and Surface Transportation in America" Act, https://transportation.house.gov/imo/media/doc/2020%20INVEST%20in%20America%20Bill%20Summary.pdf (last visited July 1, 2020) (toward zero deaths).

[194] Exec. Order 12898, 59 Fed. Reg. 7629, Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations (Feb. 11, 1994), https://www.archives.gov/files/federal-register/executive-orders/pdf/12898.pdf.

[195] *See* Aaron Golub, Richard A. Marcantonio, & Thomas W. Sanchez, *Race, Space, and Struggles for Mobility: Transportation Impacts on African Americans in Oakland and the East Bay*, 34 Urb. Geography 699, 699, 710 (2013).

[196] Shashikanth Gurram, Amy Lynette Stuart, & Abdul Rawoof Pinjari, *Agent-Based Modeling to Estimate Exposure to Air Pollution from Transportation: Exposure Disparities and Impacts of High-Resolution Data*, 75 Computers Env't Urb. Sys. 22, 22 (2019).

[197] *Id.* at 32.

[198] *Id. See also* Daria Roithmayr, *Reproducing Racism* (NYU Press 2014); National Fair Housing Alliance, *Unequal Opportunity–Perpetuating Housing Segregation in America* (April 5, 2006), https://nationalfairhousing.org/wp-content/uploads/2017/04/trends2006.pdf.

199 Wolfram Schlenker & W. Reed Walker, *Airports, Air Pollution, and Contemporaneous Health*, 83 Rev. Econ. Stud. Ltd. 768,772 (2016).

200 *Id.* at 769-70.

201 *Id.* at 771.

202 Victor Lavy, Avraham Ebenstein, & Sefi Roth, The Impact of Short Term Exposure to Ambient Air Pollution on Cognitive Performance and Human Capital Formation at 11 (Natl. Bureau of Econ. Rsch., Working Paper No. 20648, 2014), http://www.nber.org/papers/w20648.

203 *Id.* at 17.

204 Rema Hanna & Paulina Oliva, *The Effect of Pollution on Labor Supply: Evidence from a Natural Experiment in Mexico City*, 122 J. Pub. Econ. 68, 69 (2015).

205 *Id.* at 75.

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