Transportation Infrastructure Spending and Climate Outcomes

Effects of Reinvesting Transportation Carbon Fee Revenues in Transportation Infrastructure

WORKING PAPER

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Main Conclusion: *Reinvesting revenues from a transportation fuels carbon fee into targeted infrastructure improvements can achieve small decreases in GHG emissions while also improving transportation conditions and generating significant transportation-related net economic benefits; adding complementary policies, such as higher fuel efficiency requirements, achieve much larger GHG reductions and net economic benefits.*

EXECUTIVE SUMMARY

There is an underlying tension between transportation policy goals and climate policy goals: improved transportation system performance tends to promote more transportation activity, which in turn leads to more energy consumption and greenhouse gas (GHG) emissions. Despite this tension, policymakers increasingly see a role for transportation measures in climate policy, and are also looking at new transportation policies as a way to achieve climate-related goals. With the apparent demise of comprehensive climate policy in summer 2010, transportation policy is one of the few remaining near-term options for addressing climate change concerns through national policy. Yet the interaction between the two policy arenas remains largely unexplored for policymakers' needs, and ***the question of whether transportation policy can achieve desired outcomes for climate policy while also meeting transportation goals remains unanswered.*** Examining the interaction of potential climate and transportation policies should help identify and develop approaches that meet the objectives of both sets of policy interests.

This report addresses one important part of that question by exploring the likely climate and transportation outcomes if revenue from a hypothetical carbon price were returned to the transportation sector to pay for new infrastructure and maintenance. Such a combined policy would trigger some amount of reduced travel activity from the transportation sector in response to higher prices—an effect envisioned by most cap-and-trade proposals—and also provide revenue to cover much of the proposed infrastructure investment included in transportation reauthorization proposals. Over a long-term period and in the absence of other policies, road building will result in more travel and not reduce emissions. This paper seeks to answer whether this conclusion holds up if a carbon fee on transportation fuels to reduce travel emissions—and meet other goals, such as generating revenue to pay for infrastructure or reducing oil dependency—is also implemented.

> ***Key assumptions for this paper:***
> - *Carbon fee of $20/ton (increasing by 5%/year) implemented on transportation fuels (equals 17.6 cents/gallon in 2013 and 40.4 cents in 2030)*
> - *Majority of new carbon fee revenue ($30 billion/year) invested in different types of transportation infrastructure (roads, transit, freight rail)*

This policy combination is modeled for this report as a $20/ton[1] carbon price on transportation fuels starting in 2013 and increasing at 5% per year through 2030,[2] with a significant portion of new revenue returned to the transportation sector for infrastructure investment. Infrastructure spending is set at $30 billion per year above existing trends—the approximate amount of new revenue in the first year—and structured with four proportional distributions between roads, transit, and freight rail. This general scenario and the spending variations are simulated with the SIMTRAVE model developed by the Climate Change Policy Partnership (CCPP) at Duke University's Nicholas Institute for Environmental Policy Solutions. Reporting outputs include total revenue generated, carbon dioxide emissions, vehicle miles

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[1] The term *ton* (abbreviated *t*) in this paper refers to the metric ton (1 ton [or *tonne*] = 1,000 kg = 2,204.62 lbs.). Hence, the abbreviation *Mt* refers to the megaton (1 million metric tons).

[2] This amount is in the upper mid-price range from most neutral estimates of allowance prices under recent cap-and-trade proposals, but is not intended to represent any specific climate proposal (see, for example, EPA's and EIA's analyses of the American Power Act and H.R. 2454 – American Clean Energy and Security Act).

traveled, mode splits, and net economic benefit as it relates to the transportation sector. Implications from these results are not limited to a carbon fee–based revenue source, but apply to behavioral changes with any per-gallon fuel-based fee or tax equivalent to $20 per metric ton of CO_2, with the same $30 billion per year spent on transportation infrastructure.

Key cumulative results for 2013–2030 are summarized in Table ES-1, below. These show how ***increased greener transportation infrastructure investments change long-term key measures***.

Table ES-1. Cumulative changes in key measures (2013–2030).[3]

Scenario (Label)	CO_2 emissions	Road VMT	Private Vehicle PMT	Transit PMT	Net Benefits (Transportation)
Units of measure	*(Mt)*	*(billion VMT)*	*(billion PMT)*	*(billion PMT)*	*($ billion, 2007$)*
BAU reference *(baseline values)*	(*25,665*)	(*65,276*)	(*85,134*)	(*3,833*)	—
Carbon fee (20CF)	−172	−566	−724	48	−$279
$30b current spending pattern (A30_BAU)	37	109	181	38	$711
$30b "Green" road spending (A30_Green)	−10	−42	−21	40	$495
$30b 75% road, 25% transit (B30)	−46	−160	−185	66	$344
$30b equal road-transit $ split (C30)	−85	−290	−364	86	$169
$30b w/ freight rail improvements (D30)	−92	−288	−349	68	$529
CF + 4% annual CAFE increase (20CF_C)	−1,504	−571	−777	50	−$15
$30b 75% road, 25% transit + CAFE (B30_C)	−1,392	−164	−239	68	$610

Results show that ***linking some type of carbon fee on transportation fuels with "green"[4] infrastructure spending can be done without "wiping out" any policy gains***, but the type of infrastructure matters. The ***effectiveness of using carbon revenue to fund transportation infrastructure has limits for both policy arenas***, although it does achieve some appealing climate and transportation outcomes. Policymakers and stakeholders interested in linking climate and transportation policies should consider these key policy implications:

- A carbon fee by itself does not result in a large decrease in transportation GHG emissions. Targeted reinvestment of carbon fee revenues in infrastructure improvements can, however, lead to significant increases in transportation-related economic benefits and still achieve moderate decreases in GHG emissions. The economic gains from infrastructure reinvestment are large enough to make otherwise negative economic transportation policies achieve positive net economic benefits.
- An ***opportunity for synergy between the climate and transportation policy arenas exists by targeting new spending on infrastructure likely to support lower emissions:*** higher spending for maintenance, bottleneck relief, transit, etc. Although these are more likely to achieve transportation policy goals than climate goals, they do so with a less negative impact on climate goals.
- Effective application of ***transportation policy as climate policy will require using policy tools beyond a carbon price and targeted green infrastructure investments.*** The price signal sent by a relatively small increase in fuel costs is not sufficient to significantly reduce transportation emissions. Other policy tools might include higher fuel efficiency requirements, long-term planning and land-use

[3] Color-coding of results in this table and throughout this paper indicates whether a value is a desired outcome from the expected perspective of all stakeholders. Reduced emissions and positive net economic benefits are treated as desired outcomes. Travel activity (VMT and PMT) results are not color-coded; some stakeholders view more travel as a net gain, others see it as a negative. This paper doesn't address that question.

[4] The "green" transportation infrastructure modeled in this analysis is described in the "Methodology" section below. It generally includes more maintenance for existing roads, congestion relief targeting urban areas, expanded transit service, and expanded freight rail capacity.

standards, and a variety of additional pricing mechanisms. Revenue from a carbon fee could potentially help offset additional costs.
- From a climate policy perspective, the ***opportunity to achieve emissions reductions from higher fuel efficiency standards is attractive.*** New fuel economy requirements (a 4% annual increase starting in 2017)[5] generate substantially more CO_2 reductions than any price or infrastructure scenarios. When combined with a higher fuel price that funds new infrastructure, higher CAFE standards can also achieve significant net economic benefits.

Cumulative results effectively show a few important trends for policymakers to consider[6]:

- More spending on green infrastructure—as represented by road capacity that favors maintenance and bottleneck relief, more transit spending, and freight rail improvements—results in larger cumulative CO_2 reductions over all time periods.
- All scenarios with revenue reinvested in transportation infrastructure result in net economic benefit gains, with highway spending and freight rail investments apparently generating the most economic benefits. Scenarios that impose a carbon fee without reinvesting funds in infrastructure result in net economic losses from transportation, although the carbon fee revenue would probably be used for purposes that generate net gains in other sectors.
- More spending on green infrastructure reduces total vehicle miles traveled and total passenger miles traveled, while increasing transit's mode share.
- Additional fuel economy standards dramatically increase the reductions in GHG emissions without significantly different VMT or PMT results. New fuel economy standards also generate significantly higher net economic benefits.
- Freight rail system improvements achieve some of the most balanced results, with larger emissions reductions than comparable spending, large shifts to transit travel, and larger gains in economic benefits than comparable scenarios.

Annual results for VMT, CO_2 emissions, and net economic benefits related to transportation are shown at five-year intervals in Tables ES-2 to ES-4.

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[5] On September 30, 2010, the National Highway Safety Administration (NHTSA) and Environmental Protection Agency (EPA) released a preliminary proposal (Notice of Intent to Issue a Proposed Rulemaking) to increase Corporate Average Fuel Economy (CAFE) standards by 3%–6% per year from 2017 to 2025. The 4% fuel efficiency increase modeled for this report was prepared prior to that release, but is comparable in fuel efficiency and vehicle costs to the NHTSA/EPA 4% scenario.

[6] Although not modeled for this report, job-related outcomes are also a key consideration for policymakers. Using projections of different rates for job generation per billion dollars spent on different infrastructure (e.g., CNT 2010), the $30 billion in infrastructure spending scenarios modeled for this report would directly support between 263,000 and 378,000 job-months per year, or approximately 22,000–31,500 actual jobs. These figures do not include indirectly supported or generated jobs in transportation infrastructure and operations-related industries. The job-related estimates vary between spending patterns. It should also be noted that job generation is not a self-contained effect; spending this revenue in other sectors would also generate jobs, and not collecting it at all would theoretically result in consumers spending more for other expenditures, and would therefore generate new employment in sectors supported by those other expenditures.

Table ES-2. Annual vehicle miles traveled (VMT) (trillion miles).

Year	*BAU*	Carbon Fee	A30 ($ BAU)	A30 (S Green)	B30	C30	D30	*Carbon Fee_C*	*B30_C*
2010	*3.20*	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20
2015	*3.38*	3.36	3.37	3.36	3.36	3.36	3.36	3.36	3.36
2020	*3.57*	3.54	3.57	3.56	3.56	3.55	3.55	3.54	3.56
2025	*3.76*	3.72	3.78	3.76	3.76	3.74	3.75	3.72	3.76
2030	*3.96*	3.91	3.98	3.97	3.96	3.94	3.94	3.91	3.95

Table ES-3. Annual CO_2 emissions (Mt).

Year	*BAU*	Carbon Fee	A30 ($ BAU)	A30 (S Green)	B30	C30	D30	*Carbon Fee_C*	*B30_C*
2010	*1,608*	1,608	1,608	1,608	1,608	1,608	1,608	1,608	1,608
2015	*1,513*	1,507	1,510	1,509	1,508	1,508	1,508	1,507	1,508
2020	*1,424*	1,415	1,425	1,423	1,421	1,419	1,418	1,384	1,390
2025	*1,379*	1,368	1,384	1,381	1,378	1,375	1,374	1,257	1,266
2030	*1,357*	1,343	1,364	1,360	1,357	1,353	1,352	1,114	1,125

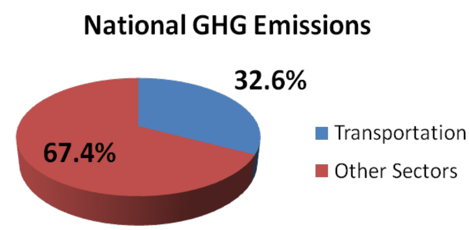
Table ES-4. Annual net economic benefits related to transportation (billion dollars, 2007$).

Year	*BAU*	Carbon Fee	A30 ($ BAU)	A30 (S Green)	B30	C30	D30	*Carbon Fee_C*	*B30_C*
2015	—	−$12.8	$5.6	$0.4	−$2.7	−$5.9	$0.0	−$12.8	−$2.7
2020	—	−$13.9	$37.2	$24.6	$16.4	$7.3	$28.3	−$7.7	$22.7
2025	—	−$16.8	$58.7	$42.8	$31.4	$17.9	$45.4	$4.8	$53.1
2030	—	−$21.1	$73.2	$56.3	$43.1	$26.4	$66.8	$24.6	$88.8

In addition to examining these specific scenarios, this paper serves to illustrate a new approach to combined climate and transportation policy analysis. Future reports will examine additional outcome measures and additional individual and combined policy scenarios that integrate climate and transportation policy objectives to increase understanding of how these two policy arenas interact and further explore how transportation policies can also serve as effective climate policies.

INTRODUCTION

There is a tension between transportation policy goals and climate policy goals: improved transportation system performance tends to promote more transportation activity, which in turn leads to more energy consumption and greenhouse gas (GHG) emissions. Transportation activity is a major source of U.S. GHG emissions, accounting for nearly one-third of total U.S. GHG emissions. Light-duty vehicles—cars, SUVs, trucks, and motorcycles—account for about 55% of transportation emissions: almost 18% of the U.S. total. The transportation sector is also the fastest-growing source of emissions (EPA 2008). Transportation policy is growth-oriented and usually designed to meet a number of goals, primarily increased mobility, but also job creation, economic development, access to jobs and shopping, and decreased freight costs. Environmental regulations in transportation focus on mitigating traditional pollutants, such as particulate matter, nitrogen oxide, volatile organic compounds, noise, etc. Under the current national transportation policy framework, climate change is a secondary concern that infrastructure spending agencies are encouraged to address when programming infrastructure, but they are not required to make infrastructure decisions that would reduce GHG emissions.



The primary interest of climate policy is to reduce GHG emissions, with a critical secondary objective of achieving those reductions in the most economically efficient manner. Minimizing the costs of potential climate policies is also an important consideration. Over the long run, GHG emissions from transportation will not decline without reducing travel activities (Morrow et al. 2010), yet transportation policy seeks to increase travel opportunities. Approximately 94% of transportation activity is dependent on petroleum, and there is only slow growth in alternate fuels (ORNL 2010). Most new transportation activity, therefore, results in more GHG emissions. The inevitable conflict, then, is between climate policy seeking lower emissions and transportation policy seeking more transportation options.

Despite this tension, policymakers increasingly see a role for transportation measures in climate policy, and are also looking at new transportation policies as a way to achieve climate-related goals. Major climate policy proposals over the past few years have increasingly attempted to introduce innovations in defining the growth-related outcomes of transportation programs. For example, recent proposals have included new planning requirements for transportation agencies that would make GHG reductions an equal—or overarching—factor in determining which infrastructure projects to build. Similarly, one recent proposal would have directly increased funding for transportation investments that facilitate lower GHG emissions: road maintenance would be favored over new facilities, and transit—which generally produces lower emissions per passenger mile—would be favored over highway construction. These proposals would have essentially changed the growth-based transportation policy orientation to one based on both growth and climate outcomes, but only for a relatively small portion of the overall transportation policy arena.

With the apparent demise of comprehensive climate policy in summer 2010, transportation policy may be one of the few remaining near-term options for addressing climate change concerns through national policy. Recognizing this, attention from a growing number of policymakers and other transportation stakeholders has turned to addressing climate policy while also meeting traditional transportation policy goals. Yet the interaction between the two policy arenas remains largely unexplored for policymakers' needs.

The core national transportation policy activity is providing and improving transportation infrastructure to support the transportation goals identified above, but the climate-related effects of infrastructure investment have not been extensively examined or modeled for policy analysis. Research over the past decade has focused on the technical potential for GHG reductions through modifying how various transportation policies are implemented, but these tend not to include infrastructure.[7] Effective policy linkage between climate and transportation will require addressing the role of infrastructure and GHG emissions, either individually or in concert with complementary policies.

Given their competing respective policy goals, the question of whether transportation policy can also function effectively to achieve climate policy outcomes remains unanswered. In addition to knowing the technical potential of policies, effective policymaking also requires information about the tradeoffs between options, how likely combinations of policies will change the effectiveness of different measures, and the policy pathways for best meeting desired objectives (Bardach 2005; Gupta 2001; Majchrzak 1984).

This working paper addresses one part of the broad question of how transportation and climate policies can interact for maximum benefit. It explores the likely climate and transportation outcomes if revenue from a hypothetical carbon price were returned to the transportation sector to pay for new infrastructure and maintenance. Such a combined policy would trigger some amount of reduced travel activity from the transportation sector in response to a carbon price—an effect envisioned by most cap-and-trade proposals—and also provide a pathway to generate new revenue to cover much of the proposed infrastructure investment included in transportation reauthorization proposals. By using a progression of scenarios making increasingly green transportation infrastructure investments, policymakers and stakeholders will be able to consider how variations in investments are likely to result in desired climate and transportation policy outcomes.

BACKGROUND: REVENUE RETURN, TRANSPORTATION POLICY COSTS, AND EFFECTS OF NEW INFRASTRUCTURE

To better understand how such a general policy scenario of spending revenue from a new carbon fee to pay for transportation infrastructure may reduce emissions while also increasing net economic benefits as they relate to transportation, three underlying concepts must be explored. First, we describe the basic concept and state of current knowledge about returning revenue to transportation as a way to generate economic benefits. Second, we establish the potential for economic gains from transportation programs. Finally, we discuss the process by which new transportation infrastructure provides benefits.

Effects of Revenue Return

Various analyses of the Kerry-Lieberman climate policy proposal[8] modeled the effects of providing a small portion of transportation-generated carbon revenue—about 1/5 of the total new revenue from transportation—as direct transfers to consumers.[9] These showed that the revenue recycling improved net

[7] Two prominent recent reports, the USDOT report to Congress, "Transportation's Role in Reducing U.S. Greenhouse Gas Emissions" (USDOT 2010) and the "Moving Cooler" report (Cambridge Systematics 2009), evaluate extensive sets of transportation sector measures for their potential to reduce GHG emissions, and examine various measures of effectiveness. These reports provide encyclopedic summaries of the state of knowledge about emissions reduction opportunities for many transportation policies, but do not include simulations of infrastructure investments or the effects of specific policies or combinations within the complex transportation system to identify optimal policy pathways.

[8] Although not introduced as a bill, the American Power Act climate proposal developed by Senators Kerry and Lieberman was the last significant comprehensive climate initiative in the Senate in 2010. It would have established a cap-and-trade system with a carbon fee on transportation fuels linked to the cap-and-trade allowance price. It would have then dedicated about $6.25 billion per year to new transportation infrastructure planning and spending programs.

[9] Although previous research has not examined the specific type of new policy approach considered here, returning carbon fee revenue generated from the transportation sector to the transportation sector is likely to provide some

consumer welfare over programs without the revenue return (see, e.g., Houser et al. 2010 and EPA 2010). These analyses, however, were unable to establish the specific effects of the transportation sector revenue recycling because the overall climate policy was highly complex, and because the actual policies in the proposal would have funded infrastructure programs.[10] Overall, a relatively large body of research supports the concept that returning transportation sector–generated revenue to the transportation sector, or directly to households, will have positive economic benefits, although little research has specifically examined the effects of returning revenue as investments in transportation infrastructure.

Transportation Emissions Abatement Costs or Benefits

Policies that reduce transportation sector emissions can have net benefits, although the range of potential benefits (and costs) identified by different studies varies widely depending on the specific assumptions used. One study makes this point most succinctly: "reducing carbon emissions from passenger vehicles may result in very large net benefits (excluding the climate benefits), rather than large costs…" (Parry 2007).[11] Another study showed that new gasoline taxes produce immediate economic benefit gains, and that a fuel tax would have lower net costs compared to new fuel efficiency standards (Austin and Dinan 2005).[12] At a macroeconomic level for the U.S., a recent study estimated a small effect on GDP with policies designed to reduce GHG emissions from the transportation sector, but that GDP would still grow

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level of consumer benefit. If the revenue is generated by some type of fuel-based mechanism, the policy would also result in some reduction of vehicle miles traveled and GHG emissions. Climate policies that implement some type of economy-wide carbon price may impose significant costs on consumers, but revenue return directly to households can alleviate the burden of higher prices (Burtraw et al. 2009). Similarly, fuel tax revenue returned to consumers as direct payments to households can have a small net positive impact of about 0.08% on household income, but results in a small net cost of about 0.10% (Bento et al. 2005). The revenue return can be structured to deliver a progressive impact based on household income (Bento et al. 2005). Returning revenue indirectly, such as with a payment to households or as an income tax credit, has a net positive effect on incomes and is more likely to reduce fuel consumption than a direct rebate or credit proportional to the amount of fuel consumption (Browning and Browning 1992).

[10] The limitation of most climate policy models to appropriately simulate transportation-related elements embedded in climate proposals was a main reason for the Nicholas Institute and Climate Change Policy Partnership to develop the SIMTRAVE model in anticipation of further overlap between climate and transportation policy initiatives.

[11] That particular report estimated annual welfare gains from tax policies that reduce transportation GHG emissions by 10% as ranging from $3.5 billion to $28.3 billion, although one approach showed a net cost of $0.2 billion.

[12] A previous related study from the Congressional Budget Office concluded that higher fuel efficiency standards have the potential to improve economic benefits if the external costs associated with consuming gasoline exceeded the average fuel tax (Congressional Budget Office 2003). (There is additional policy significance to this conclusion: given large variations in state and local fuel taxes, the same national policy could result in net economic gains in some regions and net costs in others. This CBO report used a national average of federal, state, and local fuel taxes. The Nicholas Institute SIMTRAVE model currently uses the same type of national average of fuel taxes; the next significant revision to SIMTRAVE will disaggregate data to state or regional levels. This disaggregation will allow SIMTRAVE to examine state-level transportation-related economic effects.) That CBO report's conclusion was partially based on a study that concluded that the marginal benefit from reducing fuel consumption was $0.26/gallon (National Research Council 2002). Another study estimated the external cost of congestion from an additional vehicle mile traveled is $0.035, implying that reduced VMT also affects net economic benefits (Parry and Small 2005). At that estimated benefit rate, eliminating 1 billion VMT would save about $35 million in congestion costs. A study of pay-as-you-drive insurance concluded that it could reduce VMT and fuel consumption 9.1% while increasing net economic benefits by up to $19.3 billion per year; a 150% increase in the federal gas tax would achieve the same fuel savings, but only increase economic benefits by $6.2 billion per year (Parry 2005). That report, however, assumes higher elasticity values than the SIMTRAVE model estimates, and a lower starting fuel price than SIMTRAVE.

at a slightly slower rate than without these policies; the estimated GDP growth rate is 2%–5% per year, about 1% lower than the baseline projected growth rate (Morrow et al. 2010).[13]

Effects of Spending to Improve Transportation Infrastructure

Infrastructure spending can result in a variety of benefits to the transportation system, including reduced congestion, improved mobility, lower travel costs, and lower freight movement costs (National Surface Transportation Policy and Revenue Study Commission 2008). In general, better travel conditions reduce costs and increase consumer utility and producer surplus.

Induced travel

One of the benefits of road capacity improvements—less congestion—reduces road travel costs, which in turn encourages more travel (Lee 2002). More travel increases household and business utility.[14] But any benefits gained from road improvements will be partially offset by increased demand (Downs 1962). Understanding this effect, called "induced travel," has been the focus of substantial research in the transportation community about whether new travel activity would have occurred without the new capacity because travel activity is driven by other factors like economic growth, or whether the new travel wouldn't have occurred if the new capacity had not reduced travel costs (Newman and Kenworthy 1999). Most researchers now conclude that both effects influence the "induced travel" phenomenon, but also that the scale and intensity of effects is determined by the interaction of a wide variety of factors, including demographic and economic conditions, as well as pavement quality, safety, and other physical elements of the roadway system. The induced demand concept highlights the complexity of the transportation system and the difficulty of using policies to achieve goals while avoiding unintended consequences.

General economic effects

Highway spending may reduce consumer costs, but in the absence of other policies, the immediate payback is relatively small: $0.11–$0.24 per dollar spent on new infrastructure in the same year (Winston and Langer 2006). The long-term rate of return for generating economic benefits from highway investment is higher—about $1.10 per dollar spent—and has declined over time from an average since the 1950s of $1.28 (Nelson et al. 2009). Yet even with lower current investment return rates, over a long time frame, many infrastructure investments can be expected to generate significant economic benefits. For example, a study for Georgia DOT estimated that spending $26 billion–$43 billion on carefully selected highway infrastructure in Atlanta over 30 years would generate about $119 billion in economic improvements from reduced congestion (McKinsey 2009b). Gains in economic benefits from transportation infrastructure are not limited to new roads; bus system improvements can generate benefits of $1.27 per dollar invested, and light rail is estimated to generate benefits at $1.09 per dollar spent (Nelson et al. 2009).

Transit

Transit investments for rail and buses also generate climate-related benefits of reduced GHG emissions, but highway and road-related infrastructure spending may result in higher GHG emissions. Transit capital improvements sufficient to increase annual service by 2.4%–4.6% can result in annual GHG emission reductions from transportation of 0.3%–0.8% in 2030 and 0.4%–1.5% in 2050 (USDOT 2010). A one-time $30 billion investment in light rail would result in 0.273 Mt of avoided CO_2 emissions per year, or

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[13] Other more general studies of the global transportation system also conclude that some abatement options have net benefits: policies to reduce VMT, improve traffic flow, and improve vehicle fuel economy (McKinsey 2009a).
[14] Higher utility is not the only effect from more travel; additional effects of more travel include more expenditures on transportation, more time costs during travel, and a range of externalities, such as accident and pollutant costs. The changes in utility and costs associated with more travel with different scenarios provide the net economic benefit values in this report.

about 15 Mt over 50 years (ICF International 2009). Fare reductions can further increase transit use and reduce GHG emissions (Cambridge Systematics 2009).

New roads
For new roads, however, emissions may increase with capacity. Over a period of many years and in the absence of other policies, road building will not improve travel time, save fuel, or reduce emissions (Newman and Kenworthy 1999). New construction for congestion relief alone may lead to lower emissions, but estimates that include or measure other factors—notably the lifecycle emissions from construction and maintenance of the facility—generally result in higher overall emissions from new road capacity. One study looking at bottleneck relief concluded that relieving congestion at the nation's 233 worst bottlenecks over a 20-year period would reduce cumulative CO_2 emissions by 390 Mt (American Highway Users Alliance 2004). But other studies conclude that every new lane-mile of highway results in 113 to 183 new tons of CO_2 emissions (Sightline Institute 2007). The shortfall of many of these studies, however, is that they do not examine the effect of generating revenue on travel activity and emissions; paying for the new infrastructure with an increase in the effective tax rate would probably decrease travel activity and reduce emissions.

Road maintenance
Well-maintained roads can have a positive impact on GHG emissions, and as road quality improves, vehicle GHG emissions decrease (ICF International 2009). A "road smoothing" program in Missouri was estimated to have reduced road vehicle emissions by 2.4%[15] (MoDOT 2007). The mechanism for this effect has not been extensively examined, but GHG reductions are probably due to reduced travel times and lower maintenance requirements resulting from better-maintained roads. One projection of effects presented in multiple studies concluded that spending $30 billion on road maintenance and repair over 50 years would result in cumulative emissions reductions of 2 Mt CO_2 (ICF International 2009).

Other effects
Because travel is mostly a derived demand (i.e., people travel to reach a location where they can conduct an activity, rather than simply for the sake of travel [Stopher and Meyburg 1976]), and because travel itself improves utility (Redmond and Mokhtarian 2001), policies like infrastructure capacity expansion that support more travel activity should generally generate net economic benefits. Additional potential effects from infrastructure spending—not addressed in this report—include added value to real estate, transportation-related job creation, and agglomeration economics, whereby increasing population or employment density or both increases economic productivity over time (Nelson et al. 2009).

Bottom line
The bottom line is that gaps still remain in understanding how climate and transportation policies will interact.

Examining current knowledge about revenue return, GHG abatement alternatives and costs from the transportation sector, and the effects of new transportation infrastructure provides some indications of how each works, but the combined application of different policies is still not well understood. Generally, the interactions between a carbon price, revenue return for infrastructure investment, and effects of infrastructure spending have not been adequately explored to help policymakers shape effective desired outcomes. The basic expected effects are:

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[15] This state-level program evaluation looked only at emissions from road usage. It did not examine the emissions that occurred from the maintenance program—construction vehicle equipment operations and production of road maintenance materials, which can potentially be significant. This type of "lifecycle" emission analysis is not part of this report.

- A carbon price on transportation fuels should send a price signal to transportation system users that reduces emissions. The carbon price would also generate substantial revenue to fund transportation infrastructure spending or for other purposes.
- Revenue return should help mitigate the higher fuel costs and minimize or eliminate additional costs to consumers.
- Infrastructure investment should improve transportation conditions, but when combined with a carbon price intended to reduce emissions, should not wipe out the effect of the carbon price.

The challenge for policymakers seeking to use transportation policy as a mechanism for climate policy is to find a way to reduce transportation GHG emissions while also improving transportation conditions sufficiently to minimize or eliminate the costs of GHG reductions. This report explores one potential approach for accomplishing these dual goals, but policymakers considering such an approach need to understand whether these effects will actually happen and what other factors might influence the effectiveness of such a strategy. The current state of knowledge—both academic and policy-oriented—doesn't provide these answers.

METHODOLOGY

To expand the state of knowledge about the interaction of these policy mechanisms, the Climate Change Policy Partnership (CCPP) at Duke University's Nicholas Institute for Environmental Policy Solutions simulated the effects of this integrated policy approach using an economic behavior model of the national transportation system. A total of eight scenarios were developed and simulated for this report.

SIMTRAVE Model

This paper reports results from scenarios that were simulated using the CCPP's economic behavior model of the U.S. transportation system, called SIMTRAVE (Sequential Integrated Model of Transportation Activity, Vehicles, and Emissions).[16] SIMTRAVE is a substantially revised and modified version of the European Commission's TREMOVE model that has been adjusted to accommodate particular variations in the U.S. transportation system, to simulate the effects of infrastructure changes, and recalibrated with a complete substitution of U.S. data. TREMOVE has been in use in Europe for nearly 15 years; it has been used most prominently to develop the European Commission's analysis of Europe's vehicle emissions and efficiency standards over the past decade, but has also been the primary modeling tool for many other studies and projects.[17] Reporting outputs include total revenue generated, carbon dioxide emissions, vehicle miles traveled, passenger miles traveled and mode splits, and net economic benefits related to the transportation sector.[18]

One of the key features of SIMTRAVE is how it treats travel demand. Using microeconomic behavior theory, the model assumes that transportation system users will respond to changes in the relative price of travel and adjust their behavior accordingly. SIMTRAVE explicitly models the relationship between the amount of travel activity for each mode, road type, trip purpose, time of day, and the per-mile cost of that

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[16] More detailed information about SIMTRAVE can be found at the Nicholas Institute's website (http://nicholasinstitute.duke.edu) or by contacting the author of this report directly at craig.raborn@duke.edu.
[17] Complete information about TREMOVE can be found at www.tremove.org and at the website for TML Leuven, the transportation consulting firm that operates the model for the European Commission.
[18] The value of time is an important component of SIMTRAVE's operations and economic outputs. SIMTRAVE uses value-of-time estimates that range from $2.52/hour to $43.80/hour, depending on trip purpose (home-based nonwork, home-based work, and non-home-based work), time of day (peak or off-peak), trip distance, and mode. These are based on value-of-time estimates from the Bureau of Labor Statistics, Texas Transportation Institute, and numerous other reports and studies. Details will be provided in the SIMTRAVE documentation; please contact the author of this report for more information at craig.raborn@duke.edu.

travel. As costs change, transportation system users respond by changing travel alternatives to maximize their utility while staying within aggregate household budgets (for consumers) or minimize their transportation costs while maximizing the amount of travel or freight movement (for businesses). In addition to increasing or decreasing total travel activity (overall and by trip purpose), travel may substitute between modes, road types, urban/rural regions, and time of day. Changes in system costs will increase or suppress transportation activity for each travel alternative.

The scenarios modeled for this report establish additional infrastructure spending above current projections. The Nicholas Institute model doesn't directly consider the financial element of new spending, but simulates the spending based on the effect it has on the transportation system's performance. Highway and road spending is modeled as increased road and highway capacity; transit spending is modeled as increases in the system extent and number of vehicles; and freight rail spending is modeled as increases in travel speed for freight rail transportation.

Policy Scenarios

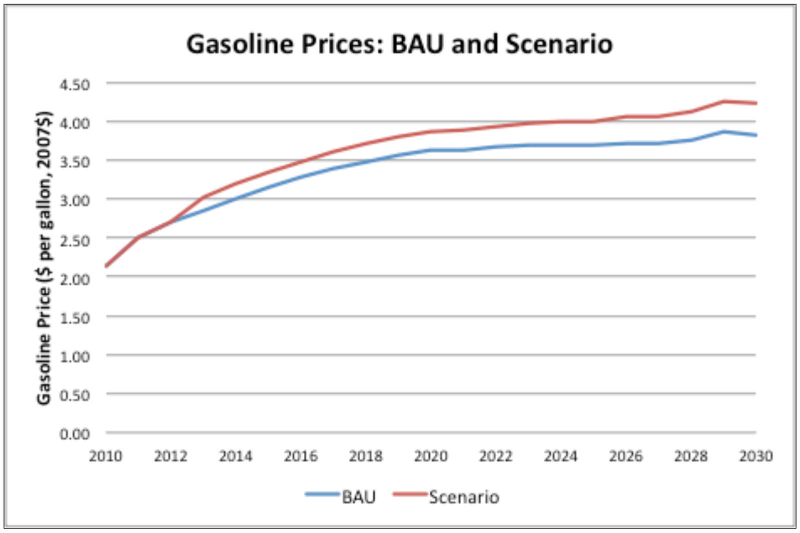
Five core policy scenarios were developed for this report, along with a reference case and two supplemental scenarios to examine potential impacts of increased fuel efficiency standards.

The overall policy combination of applying a carbon fee and using the revenues for new infrastructure is modeled for this report as a $20/ton carbon price starting in 2013 and increasing at 5% per year through 2030, with partial revenue return for infrastructure investment. Figure 1 shows the carbon price converted to a per-gallon fee and added to baseline fuel prices. Infrastructure spending is set at $30 billion per year above existing trends—the approximate amount of new revenue in the first year[19]—and structured with a variety of proportional distributions between roads, transit, and freight rail.

A carbon price of $20/ton applied to transportation fuels will not itself have a significant effect on total transportation activity. This amount would result in a per-gallon carbon fee of $0.176[20] for gasoline in 2013, increasing to $0.404 in 2030; such a price change could easily fall within the range of historic annual variations, so the carbon fee might be mostly lost in the common price variations consumers already see (Raborn 2009). Transportation activities are highly inelastic, meaning that travel activity will change at a smaller rate than fuel prices. Despite the general inelasticity of transportation to small price changes, a $20/ton carbon price such as the one used in these scenarios would likely result in a small-to-moderate effect on the amount of travel activity (Raborn 2009).

[19] The $30 billion infrastructure investment matches the first year new revenue from the scenario's carbon fee. As described in the results portion of this report, revenue would increase each year. The scenario spending, however, stays level at $30 billion/year.
[20] All dollar figures reported as modeling results in this report are 2007 dollars.

Figure 1. Gasoline prices through 2030, business-as-usual (BAU) and $20/ton scenario.



Infrastructure spending at $30 billion per year starts in 2014 with the scenarios reported in this working paper. The amount is approximately equal to the amount of new revenue that would be generated in the first year—2013—by a $20/ton carbon fee applied to transportation fuels. A series of reports in recent years on the state of national transportation infrastructure have identified significant need for additional spending, ranging from about $38 to $175 billion per year.[21] (ASCE 2009; National Surface Transportation Policy and Revenue Study Commission 2008; AASHTO 2007) The $30 billion spending scenarios used here would provide a significant portion of that funding gap. Funding levels for different types of infrastructure (roads, transit, and freight rail) vary between scenarios.

For roads, three basic levels of new infrastructure spending are modeled: $30 billion, $22.5 billion, and $15 billion per year. Two levels of transit spending are modeled: $15 billion and $7.5 billion per year. $15 billion for transit spending would approximately double historical annual transit capital funding (AASHTO 2009), is slightly more than the amount recommended by the Federal Transit Administration to meet agency targets for "State of Good Repair" standards (FTA 2010), and is close to the additional amount above current capital spending to reach and maintain FTA's targeted "Annual Asset Condition Rating" (FTA 2010). A single level of investment for freight rail improvement is modeled: $7.5 billion per year, which is approximately the annual investment for rail infrastructure expansion recommended by the "National Rail Freight Infrastructure Capacity and Investment Study" (AAR 2007). These different spending levels for road capacity expansion, transit system expansion, and freight rail capacity expansion are combined into the five main scenarios shown in Table 1.

[21] These estimates include spending from all sources: federal, state, and local. Federal spending historically makes up about 45% of total transportation spending. Because this report examines a hypothetical national transportation fuel carbon fee, it only looks at new federal spending.

Table 1. Scenario descriptions.

Scenario Description (Label)	Annual Spending	Infrastructure Spending		
		Roads	Transit	Freight Rail
Reference/BAU (BAU)	—	—	—	—
$20/ton Carbon Fee (20CF)	—	—	—	—
CF & $30b/yr BAU spending (A30_BAU)	**$30 billion**	**100% ($30.0b)**	**0**	**0**
CF & $30b/yr Green spending (A30_Green)	**$30 billion**	**100% ($30.0b)**	**0**	**0**
CF & $30b/yr Green spending (B30)	**$30 billion**	**75% ($22.5b)**	**25% ($7.5b)**	**0**
CF & $30b/yr Green spending (C30)	**$30 billion**	**50% ($15.0b)**	**50% (15.0b)**	**0**
CF & $30b/yr Green spending (D30)	**$30 billion**	**50% ($15.0b)**	**25% ($7.5b)**	**25% ($7.5b)**
$20/ton CF w/4% fuel eff /yr (20CF_C)	—	—	—	—
CF & $30b/yr w/4% fuel eff/yr (B30_C)	$30 billion	75% ($22.5b)	25% ($7.5b)	0

For road infrastructure, all but one scenario assume that spending targets maintenance over new capacity, and focuses new infrastructure capacity specifically on bottleneck relief, without adding substantial capacity that would result in economic disagglomeration[22] and subsequent land development-induced traffic increases.[23] These assumptions are operationalized in the CCPP's SIMTRAVE model by weighting road capacity spending towards existing urban areas rather than rural areas (using a 2:1 ratio), and by assuming that spending a larger proportion for maintenance and targeting bottleneck relief would mean that less actual capacity is added for every dollar spent. The "A30_BAU" scenario simulates how current spending patterns would increase capacity. The "A30," "B30," "C30," and "D30" (and "B30_C") scenarios assume that each dollar of spending results in 70% of the BAU capacity.[24] Higher costs to achieve system improvements targeted on maintenance and non-growth-inducing capacity in urban areas is conceptually borne out in a number of estimates of road infrastructure costs. Urban road construction is about three times more expensive than building comparable new roads in rural areas, and adding lane-miles costs up to 24 times more per mile than resurfacing a road for maintenance (author's analysis of Highway Economic Requirements System [HERS] database). In the real world of highway infrastructure spending, there are many ways to distribute $30 billion in new funds for "green" infrastructure projects; specific projects can have widely varying costs, making it nearly impossible to create a precisely accurate scenario to simulate this investment. The scenarios here are approximations based on best available spending information, and do not model any specific investments or projects.

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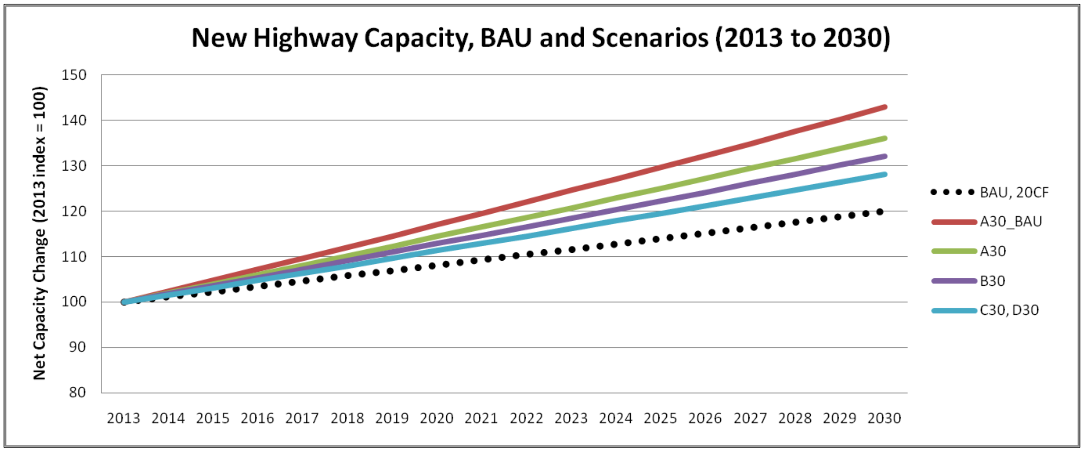
[22] The concept of economic agglomeration was described earlier. As population and employment densities increase, so does economic activity and growth. We use the term *economic disagglomeration* to describe the opposite trend: lower population and employment density which results in reduced economic growth. Travel distances and costs are thought to play a significant role (Nelson et al. 2009). Transportation infrastructure may play an important role in this agglomeration concept: if new road capacity near undeveloped land areas tends to result in low-density housing development and low-density employment facilities, then longer average travel distances would then result in economic disagglomeration.

[23] Implementing these assumptions as policy would itself be a difficult challenge, but policies for targeted infrastructure spending can be developed (see, e.g., proposals in Nelson et al. 2009; Puentes 2009; AASHTO 2010; and Transportation for America 2009). This report assumes those investment policies are implemented as part of the carbon fee and spending program. The results of this report may help bolster the case for those types of policies, as well.

[24] Capacity in the CCPP's model is an internal calculated value (aggregate vehicles per urban and rural road type per multi-hour peak travel time period) that functions well for calculating the economic behavior response to policy and cost changes, but doesn't directly translate into values that are frequently used for transportation policy analysis. The model uses that capacity value in a modified version of the standard Bureau of Public Roads volume-to-capacity function ("BPR curve") to estimate traffic speeds and volumes, which eventually are converted to VMT. Other elements of the CCPP's model are briefly described elsewhere in this report.

Highway capacity improvements as a percentage change from total road capacity in 2013 are shown in Figure 2. Capacity increases in the background of the Nicholas Institute model's reference case, and therefore in all scenarios. In the business-as-usual (BAU) scenario, total highway capacity in 2030—without additional spending funded by the carbon fee—increases by about 20%. By comparison, total highway capacity in the scenarios with $30 billion invested in various forms of new capacity increases by about 28%–42%. In Figure 2, any capacity above the "BAU_20CF" case is the result of new spending.

Figure 2. Aggregate highway capacity changes in modeled scenarios.



Transit investments are treated as capital expenditures that expand transit system extent and add new vehicles. Investments in these scenarios and the Nicholas Institute model are based on the Federal Transit Administration's methods for modeling new transit system service as described in the documentation for the Transit Economics Requirements Model (TERM). For this report, $1 billion in transit investments increases transit service by 0.2%. Because transit systems have lower GHG emissions per passenger mile than car-road use, transit is assumed to be a "green" infrastructure. The Federal Transit Administration estimates that cars and trucks average 0.96 pounds of CO_2 emissions per passenger mile, while transit modes average 0.65 (bus transit) to 0.22 (van pool) (Federal Transit Administration 2009).[25]

Expansions of freight rail capacity were modeled using increases in the travel speed of freight rail trains as a proxy measure.[26] Using the "cost of improvements" information from the "National Rail Freight Infrastructure Capacity and Improvement Study" (Association of American Railroads 2007), an annual investment in rail infrastructure of $1 billion is estimated to produce an approximately 0.675% capacity

[25] The cost of new transit service used for this report is mainstream: the average calculated cost of system expansion over multiple capital investment scenarios in AASHTO's 2009 "Bottom Line" report indicates that $1 billion of infrastructure spending increases system capacity by about 0.285% (AASHTO 2009). Analysis of data and results using TERM, which models investments based on service degradation for individual transit systems rather than as a national transit system investment, indicates that $1 billion in new spending would achieve net service expansions of 0.18% to 0.35%.

[26] SIMTRAVE does not use a rail volume-to-capacity component, so the travel speed parameter provides the ability to estimate a significant improvement in service. To accomplish this, capacity improvements are converted to comparable travel speed improvements. To avoid overestimating the effect of capacity improvements, this conversion is conservatively kept at 20%: if an infrastructure investment doubles current capacity, the travel speed change is modeled as a 20% increase. SIMTRAVE applies travel speed to its cost-per-mile calculations, and time costs make up nearly 95% of freight rail's costs per mile, so this conservative estimate is appropriate. This method results in artificially high freight rail travel speeds at higher levels of infrastructure investment, but within the structure of SIMTRAVE the speed effect does not influence other modes.

improvement. For this report, then, $1 billion converts to a 0.135% increase in freight rail train travel speed.

The scenarios developed for this paper also include two alternatives that add 4% annual increases in vehicle fuel efficiency standards. The results from scenarios are described in the discussion below of how CAFE standards affect key measures.

RESULTS

Analysis of this general policy concept using specific spending variations modeled with the CCPP's SIMTRAVE model provides the following key results:

Cumulative Scenario Results

Cumulative results from all scenarios for GHG emissions reductions, VMT reductions, total and transit-only passenger miles traveled changes, spending, and net economic benefits related to transportation are shown in the following tables. Table 2 summarizes cumulative results in the first seven years (2013–2020), Table 3 presents results from the latter modeled period (2021–2030), and Table 4 includes the cumulative results for the entire 2013–2030 period of scenario effects.

Specific results for each key outcome are discussed in later sections, but these cumulative results effectively show a few important trends for policymakers to consider[27]:

- More spending on green infrastructure—as represented by road capacity that favors maintenance and bottleneck relief, more transit spending and introducing freight rail improvements—results in larger cumulative CO_2 reductions over all time periods.
- More green infrastructure spending reduces total vehicle miles traveled and total passenger miles traveled, while increasing transit's mode share.
- All scenarios with revenue reinvested in transportation infrastructure result in net economic benefit gains, with highway spending and freight rail investments apparently generating the most economic benefits. Scenarios that impose a carbon fee without reinvesting funds in infrastructure result in net economic losses from transportation, although the carbon fee revenue would probably be used for purposes that generate net gains in other sectors.
- Additional fuel economy standards would dramatically increase the reductions in GHG emissions without significantly different VMT or PMT results. New fuel economy standards also generate significantly higher net economic benefits.
- Freight rail system improvements achieve some of the most balanced results, with larger emissions reductions than comparable spending, large shifts to transit travel, and larger gains in economic benefits than comparable scenarios.

[27] Although not modeled for this report, job-related outcomes are also a key consideration for policymakers. Using projections of different rates for job generation per billion dollars spent on different infrastructure (e.g., CNT 2010), the $30 billion in infrastructure spending scenarios modeled for this report would directly support between 263,000 and 378,000 job-months per year, or approximately 22,000–31,500 actual jobs. These figures do not include indirectly supported or generated jobs in transportation infrastructure and operations-related industries. The job-related estimates vary between spending patterns. It should also be noted that job generation is not a self-contained effect; spending this revenue in other sectors would also generate jobs, and not collecting it at all would theoretically result in consumers spending more for other expenditures, and would therefore generate new employment in sectors supported by those other expenditures.

Table 2. Cumulative changes in key measures (2013–2020).

	CO_2 emissions	Road VMT	Private Vehicle PMT	Transit PMT	New Spending	Net Benefits (Transportation)
	(Mt)	*(billion VMT)*	*(billion PMT)*	*(billion PMT)*	*($ billion)*	*($ billion, 2007$)*
BAU	*(11,875)*	*(27,485b)*	*(35,750b)*	*(1,616b)*	—	—
20CF	–58	–197	–254	17	—	–$105
A30_BAU	–14	–53	–63	15	$210 b	$117
A30_Green	–26	–92	–113	16	$210 b	$59
B30	–34	–119	–151	22	$210 b	$23
C30	–42	–146	–187	25	$210 b	–$17
D30	–44	–146	–185	22	$210 b	$54
20CF + CAFE	–120	–191	–247	17	—	–$93
B30 + CAFE	–96	–112	–143	21	$210 b	$34

Table 3. Cumulative changes in key measures (2021–2030).

Scenario	CO_2 emissions	Road VMT	Private Vehicle PMT	Transit PMT	New Spending	Net Benefits (Transportation)
	(Mt)	*(billion VMT)*	*(billion PMT)*	*(billion PMT)*	*($ billion)*	*($ billion, 2007$)*
BAU	(13,790)	(37,791)	(49,384)	(2,217)	—	—
20CF	–113	–369	–470	31	—	–$173
A30_BAU	51	163	244	23	$300 b	$593
A30_Green	16	50	93	25	$300 b	$436
B30	–12	–42	–35	44	$300 b	$322
C30	–43	–145	–176	60	$300 b	$186
D30	–49	–143	–164	46	$300 b	$475
20CF + CAFE	–1,384	–380	–529	34	—	$78
B30 + CAFE	–1,296	–52	–96	47	$300 b	$575

Table 4. Cumulative changes in key measures (2013–2030).

Scenario	CO_2 emissions	Road VMT	Private Vehicle PMT	Transit PMT	New Spending	Net Benefits (Transportation)
	(Mt)	*(billion VMT)*	*(billion PMT)*	*(billion PMT)*	*($ billion)*	*($ billion, 2007$)*
BAU	*(25,665)*	*(65,276)*	*(85,134)*	*(3,833)*	—	—
20CF	–172	–566	–724	48	—	–$279
A30_BAU	37	109	181	38	$510 b	$711
A30_Green	–10	–42	–21	40	$510 b	$495
B30	–46	–160	–185	66	$510 b	$344
C30	–85	–290	–364	86	$510 b	$169
D30	–92	–288	–349	68	$510 b	$529
20CF + CAFE	–1,504	–571	–777	50	—	–$15
B30 + CAFE	–1,392	–164	–239	68	$510 b	$610

Summary Results

Specific results from these scenarios include the following key points:

- ***A carbon price on transportation fuels can generate substantial potential new revenue.*** Annual carbon fee revenue in 2013 would be about $31 billion, and increase to about $62 billion in 2030. Cumulative new revenue from 2013 to 2020 would total about $280 billion; over the model's full 2013–2030 period new revenue would be about $793 billion. Policymakers could reinvest this revenue for transportation infrastructure, use it for other transportation sector programs, or apply it to other policy objectives in other sectors. This report assumes that $30 billion of the revenue is reinvested for transportation infrastructure starting in 2014; such an investment totals $510 billion by 2030, leaving about $283 billion for other purposes not modeled here. From a federal perspective, ***this policy approach would not require deficit spending and would probably generate surplus revenue.***

- Applying a carbon price to transportation fuels and using a portion of the revenue to fund substantial ***green transportation spending and investment doesn't significantly affect GHG emissions or related climate policy goals.*** From 2013 to 2030, cumulative CO_2 emissions would decrease between 10 and 92 Mt (a decrease of approximately 0.05% to 0.4% below the BAU case of 25,665 Mt) with this policy combination, and 172 Mt (0.7% of BAU) with a carbon fee that is not reinvested in transportation infrastructure improvements.
- Overall ***passenger travel slightly decreases, and transit's share of travel increases under most scenarios.*** The largest decrease in total passenger travel (0.6% in 2015, 0.9% in 2030) occurs with just the carbon fee and no funds reinvested in infrastructure.
    - ***Infrastructure investments trigger a rebound in passenger travel,*** resulting in total passenger travel decreases ranging from 0.3% to 0.4% in 2015 and 0.2% to a gain of 0.3% in 2030, depending on the type of infrastructure. Spending $30 billion under historical investment trends (i.e., mostly building new road capacity) also eliminates the carbon fee effect, with an increase in passenger travel of 0.6% in 2030.
    - ***Larger investments in transit systems result in larger shifts of passenger travel toward transit.*** Spending half of these new funds on transit infrastructure results in a 2.0% increase in transit passenger miles in 2020 and a 3.2% increase in 2030; spending 25% of new funds on transit results increases of 1.6% in 2020 and 2.3% in 2030. Transit, however, remains at just over 4% of total passenger miles traveled with all scenarios, so the emissions effect from travel shifting to transit is relatively small.
- ***New infrastructure spending provides potentially large gains in net economic benefits related to transportation activity.*** Net economic benefits (changes in transportation household and producer utility and costs) from 2013 to 2020 range from a decrease of $17 billion to an increase of $59 billion, depending on the type of green infrastructure developed. Most of these economic gains are the result of savings in travel time due to investments that improve travel conditions and relieve bottlenecks and congestion without inducing new growth in VMT. Over the entire 2013–2030 period, net economic benefits are $169 billion–$529 billion; with total new infrastructure spending at $510 billion, each dollar spent generates $0.33–$1.04 in economic benefits related to transportation activity.
- ***Adding vehicle fuel efficiency requirements significantly boosts CO2 reductions.*** With the general policy scenario of this report and new fuel efficiency requirements starting in 2017 (continuing the current prescribed basic improvement rate for 2013–2016), cumulative emissions over the entire 2013–2030 period would decrease between 1,392 and 1,504 Mt (about 5.4%–5.8% of BAU).
    - The effects from higher fuel efficiency standards grow rapidly over time as the vehicle fleet changes; cumulative CO_2 emissions from 2013 to 2020 would decrease between 96 and 120 Mt (about 0.8% to 1.0% of business as usual). The cumulative decrease over the 2021–2030 period is more than 10 times larger.
    - Overall, CO_2 emissions reductions with new fuel efficiency improvements are much larger than the effect induced by just a carbon fee with or without infrastructure reinvestment: the effect in this report ranges from 8 to 30 times larger with new fuel efficiency requirements.
    - Higher fuel efficiency requirements also result in substantial net economic benefits. By 2020, annual economic benefits are about $6.5 billion higher with new fuel efficiency standards; by 2030, economic benefits are about $45 billion higher per year with new fuel efficiency standards.

Carbon fee can generate substantial revenue

Annual revenue in 2013 from a carbon fee applied to transportation fuels would be approximately $31 billion, and increase to about $62 billion in 2030 for each of the main scenarios (A30_B, A30, B30, C30, and D30). Cumulative new revenue from 2013 to 2020 would total about $280 billion; ***over the model's full 2013–2030 period new revenue from a carbon fee would be about $793 billion.*** This revenue could be reinvested for transportation sector investments (as modeled for this report), used for other transportation sector programs, or applied to other policy objectives in other sectors.

Table 5. Combined annual fuel tax and carbon fee revenue (billion $2007).

Year	*BAU*	Carbon Fee	A30 ($ BAU)	A30 (S Green)	B30	C30	D30	*Carbon Fee_C*	*B30_C*
2010	*$34.9*	$34.9	$34.9	$34.9	$34.9	$34.9	$34.9	$34.9	$34.9
2015	*$32.9*	$66.0	$66.1	$66.1	$66.1	$66.1	$66.0	$66.0	$66.1
2020	*$31.1*	$70.7	$71.2	$71.1	$71.0	$70.9	$70.9	$69.2	$69.5
2025	*$30.2*	$79.1	$80.0	$79.8	$79.7	$79.5	$79.5	$72.7	$73.2
2030	*$29.7*	$91.1	$92.4	$92.2	$92.0	$91.7	$91.7	$75.6	$76.3

Annual revenue and cumulative new and total revenues through 2030 vary only minimally between similar scenarios. Table 5 presents the expected combined revenue from the current fuel tax and the carbon fee modeled for this report. Figure 3 shows how total annual revenue is clustered among scenarios with the same carbon fee and spending levels. Higher vehicle fuel efficiency requirements (discussed later in this report) result in lower new annual revenue because they will reduce overall fuel consumption. The downward trend in fuel tax revenue shown in Table 5 and Figure 3 matches with general trends and analysis about long-term revenue with current fuel taxes; this trend in reduced projected revenue is one reason policymakers are searching for additional revenue streams that will stable over a long-term period. Cumulative revenues are summarized in Table 6.

Figure 3. Total fuel-based revenue: current fuel tax and carbon-based fee.

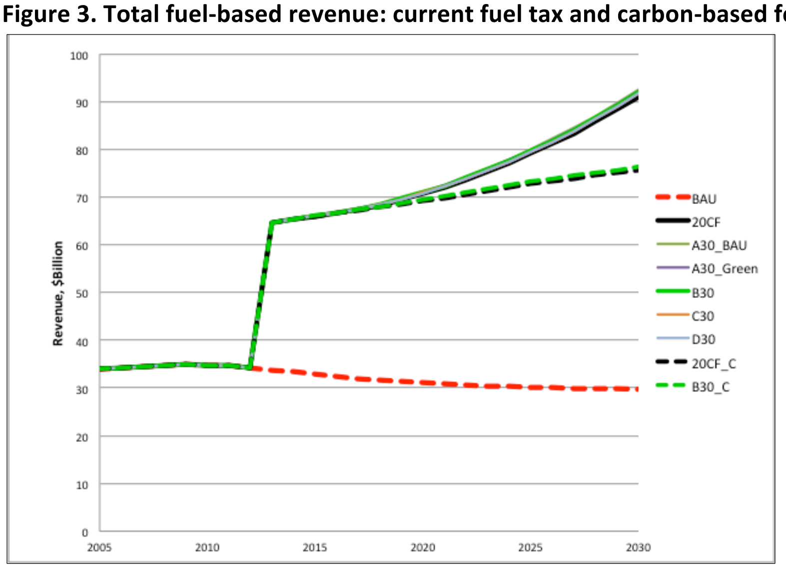


Table 6. Cumulative revenue, 2013–2030 ($ billion, 2007$).

Scenario	Total Revenue	New Revenue	Spending	Unspent New Revenue
BAU	$560 b	—	—	—
20CF	$1,346	$786	—	$786
A30_BAU	$1,357	$797	$510 b	$287
A30_Green	$1,355	$795	$510 b	$285
B30	$1,353	$793	$510 b	$283
C30	$1,351	$791	$510 b	$281
D30	$1,350	$790	$510 b	$280
20CF + CAFE	$1,264	$704	—	$704
B30 + CAFE	$1,271	$711	$510 b	$201

As Table 6 shows, for those scenarios with new infrastructure investments, a significant amount of revenue is not spent on transportation infrastructure, and could be used for a variety of purposes. Without the new carbon revenue modeled in these scenarios, annual revenue from current federal fuel taxes in the BAU case would decrease from 2013 to 2030 by about 12%. Such a shortfall in current highway user revenue—consistent with current revenue projections—might lead to continued difficulty in meeting transportation system infrastructure needs. A carbon fee would not just provide revenue for new spending, but could also provide revenue to maintain current spending. Doing so would still leave about $170 billion of cumulative new revenue unspent.[28]

Reinvestment doesn't significantly change GHG emissions

Implementing a $20/ton carbon fee on transportation fuels will result in slightly lower CO_2 emissions from transportation activity, while new transportation infrastructure funded by spending $30 billion per year on maintenance and capacity expansion will slightly increase transportation activity, but whether or not the emissions rebound is enough to wipe out the emissions reductions triggered by the carbon fee depends on the investment pattern. Spending some of the new revenue for transit or rail avoids this wipeout effect; spending all the new revenue on roads eventually results in higher emissions than the BAU trends.

For the entire period covered by this report, 2013–2030, cumulative CO_2 emissions would decrease between 10 and 92 Mt (a decrease of approximately 0.05% to 0.4% below the BAU case of 25,665 Mt) with this policy combination reinvesting in green infrastructure, and 172 Mt (0.7% of BAU) with a carbon fee that is not reinvested in transportation infrastructure improvements. For the initial 2013–2020 period, cumulative CO_2 emissions would decrease between 26 and 44 Mt (about 0.3% of the 11,875 Mt in the BAU case) with this policy combination, and 58 Mt (0.5% of BAU) with only the carbon fee.

[28] This estimated value assumes that core fuel tax–funded spending would increase at 1% per year from the 2013 level of $33.8 billion, and that the difference for this new spending level and the BAU-estimated revenue is then subtracted from the carbon fee revenue before any of the new revenue is used for additional infrastructure spending or for other purposes. This assumption was not simulated for this report, but overall infrastructure spending amounts would be higher than those reported here. Such additional spending would affect emissions, VMT and PMT, and transportation-related net economic benefits, but the scale of those differences would require additional modeling.

Table 7. Annual changes in road transportation CO_2 emissions (actual values, Mt CO_2).

Scenario	2015	2020	2025	2030
BAU	*1,513 Mt*	*1,424 Mt*	*1,379 Mt*	*1,357 Mt*
20CF	1,507	1,415	1,368	1,343
A30_BAU	1,510	1,425	1,384	1,364
A30_Green	1,509	1,423	1,381	1,360
B30	1,508	1,421	1,378	1,357
C30	1,508	1,419	1,375	1,353
D30	1,508	1,418	1,374	1,352
20CF_C	1,507*	1,384	1,257	1,114
B30_C	1,508*	1,390	1,266	1,125

* Scenarios 20CF_C and B30_C both start higher fuel efficiency standards in 2017, so there is no different effect for 2015 from their comparable non-CAFE scenarios.

Table 7a. Annual changes in road transportation CO_2 emissions (as percent different from BAU).

Scenario	2015	2020	2025	2030
BAU	*1,513 Mt*	*1,424 Mt*	*1,379 Mt*	*1,357 Mt*
20CF	−0.4%	−0.6%	−0.8%	−1.0%
A30_BAU	−0.2%	0.1%	0.4%	0.5%
A30_Green	−0.3%	−0.1%	0.1%	0.2%
B30	−0.3%	−0.2%	−0.1%	0.0%
C30	−0.4%	−0.3%	−0.3%	−0.3%
D30	−0.4%	−0.4%	−0.4%	−0.4%
20CF_C	−0.4%*	−2.8%	−8.8%	−17.9%
B30_C	−0.3%*	−2.4%	−8.2%	−17.1%

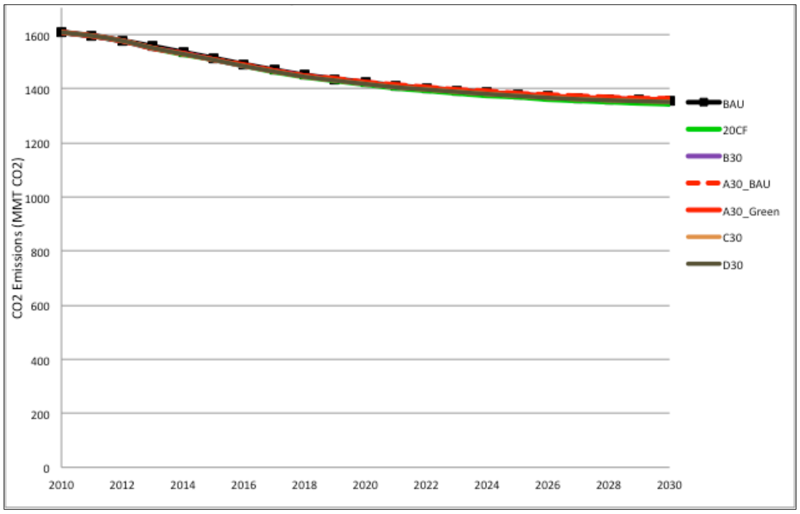
* Scenarios 20CF_C and B30_C both start higher fuel efficiency standards in 2017, so there is no different effect for 2015 from their comparable non-CAFE scenarios.

The two broad results from Tables 7 and 7a are that increasing "green" infrastructure investments (generally moving from top to bottom in the table) results in larger amounts of avoided emissions, and that as these "green" investments continue over time (moving left to right in the table), the amount of avoided emissions for each scenario grows. Similarly, investments focused only on roads—both expansion and maintenance—result in higher emissions over time.

Higher fuel efficiency standards starting in 2017 have a dramatic effect for cumulative on-road emissions; by 2020, they result in 5 to 12 times the amount of avoided annual emissions as do comparable scenarios without new vehicle fuel economy standards. In 2030, higher fuel efficiency standards are about 18 to 25 times more effective at avoiding CO_2 emissions than a transportation carbon fee with or without new infrastructure spending. Existing CAFE standards also affect the overall BAU trend showing reduced CO_2 emissions from 2013 to 2030 (top row in Table 7); without the current 2012–2016 CAFE standards implemented in the CCPP's model, baseline BAU emissions would grow annually.

Figure 4, which shows the total on-road CO_2 emissions for all scenarios except those with higher CAFE standards, emphasizes the relatively small scale of effect for emissions reductions from a carbon fee on transportation fuels combined with infrastructure reinvestment (results from scenarios with higher CAFE standards are shown in Figure 13, later in this report). None of the scenarios examined for this working paper, however, result in emissions higher than the BAU scenario.

Figure 4. Transportation on-road emissions.



These cumulative results are comparable to estimates in previous research. One recent study estimated that spending $30 billion as a one-time investment in new highway lane-miles and using current spending patterns would result in an additional 98–160 Mt CO_2 emissions over a 50-year period[29] (ICF International 2009). This 50-year emission increase would translate to approximately 34–55 Mt new CO_2 emissions by 2030, and an average increase of 1.97–3.24 Mt per year. The scenarios from this report don't compare exactly to that example, but analysis of emissions under the carbon fee scenario ("20CF") and the scenario that would invest $30 billion/year using current patterns ("A30_BAU") implies that the annual emissions increase of the first year's $30 billion investment would probably range from 1.4 to 4.5 Mt per year until 2030. Previous research, however, has not examined the dynamics feedbacks caused by imposing the carbon fee, changing system-wide travel activity, or adding an additional $30 billion in spending each year, each of which influence the CCPP's transportation system model. So the emissions results presented in this report are quantitatively comparable to previous research when considering those effects.

Infrastructure spending slightly influences transportation activity and modal shares

Overall passenger travel decreases for most scenarios, and transit's share of travel increases under all scenarios, although the absolute changes are relatively moderate. But understanding the trends can inform policymakers about how the relative demand for different transportation infrastructure changes with different revenue and spending approaches. For example, lower levels of road travel potentially reinforce the benefit of building green transportation infrastructure over simply adding capacity. Similarly, policies that result in increased transit passenger travel might bolster the case for improving the transit system.

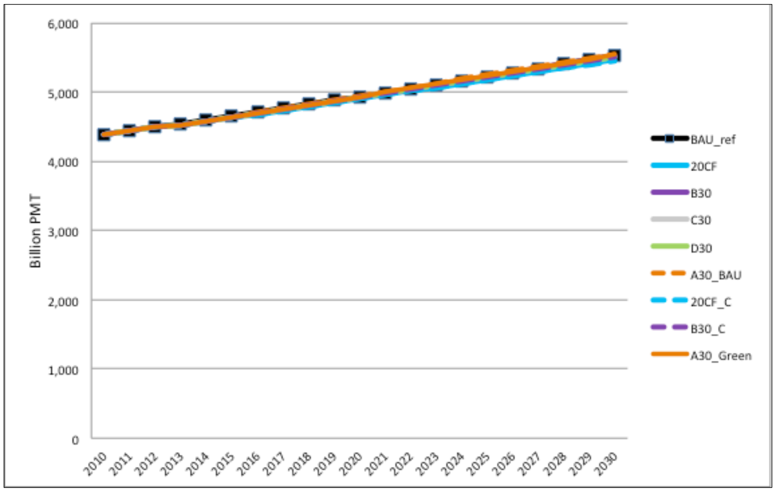
The largest decrease in cumulative passenger travel (0.6% in 2015, 0.9% in 2030) occurs with just the carbon fee and no funds reinvested in infrastructure. Infrastructure investments trigger a slight rebound in total passenger travel, resulting in total passenger travel decreases of 0.3% to 0.5% in 2015 and ranging from a decrease of 0.2% to an increase of 0.3% in 2030, depending on the type of green infrastructure.

[29] These values are adjusted to remove lifecycle emission components, such as emissions from vehicle manufacturing, road construction, and petroleum production that are not currently operational in the Nicholas Institute model. These are valid considerations, however, and would increase the values presented here by about 25%: total additional emissions per new lane-mile over 50 years of 131–213 Mt CO2, about 45–73 Mt by 2030, and an average increase of 2.62–4.26 Mt per year.

Spending $30 billion under historical investment patterns also eliminates the carbon fee effect, with an increase in passenger travel over BAU trends of 0.6% in 2030.

These cumulative values, however, are relatively small. Figure 5 shows the relatively tight clustering of annual passenger miles traveled with these scenarios: it is almost impossible to visually discern the differences. A carbon fee leads to a 0.9% decrease in total PMT by 2030, but the annual difference in 2030 for the scenarios with infrastructure spending is a range of only 0.8% (−0.2% to +0.6%). These emphasize that ***transportation activity is inelastic and doesn't significantly change with either the higher costs of the carbon fee or with the lower per-mile costs resulting from improved infrastructure.***

Figure 5. Passenger miles traveled (PMT), all modes.



Although total passenger travel decreases under all scenarios (see Figure 5 and Table 8), travel using transit—bus, light-rail, and commuter rail—increases.[30] Higher fuel prices for cars and trucks shift some travel to transit, and improved transit systems explain a portion of the increase. Larger investments in transit systems result in larger shifts of passenger travel toward transit. Spending half of the new carbon fee-generated funds—about $15 billion/year—on transit infrastructure results in a 2.0% increase in transit passenger miles in 2020 and a 3.2% increase in 2030; spending 25% of new funds—about $7.5 billion/year—on transit results increases of 1.6% in 2020 and 2.3% in 2030 (see Figure 6 and Table 9).

[30] Increased transit ridership reported in this paper should be thought of as the minimum increase; the CCPP's SIMTRAVE model is calibrated on empirical data from 1995 to 2007, a period of time that did not include substantial ridership growth. A change in conditions that results in significant improvements to transit ridership might therefore not generate a large change in ridership in the model's results.

Table 8. Annual passenger miles traveled (PMT) (trillion miles).

Scenario	2015	2020	2025	2030
BAU	*4.66*	*4.94*	*5.22*	*5.52*
20CF	4.63	4.90	5.18	5.47
A30_BAU	4.64	4.95	5.25	5.55
A30_Green	4.64	4.94	5.23	5.54
B30	4.64	4.93	5.22	5.53
C30	4.64	4.92	5.21	5.51
D30	4.64	4.92	5.21	5.51
20CF_C	4.63	4.90	5.18	5.45
B30_C	4.64	4.93	5.22	5.51

Figure 6. Transit passenger miles traveled.

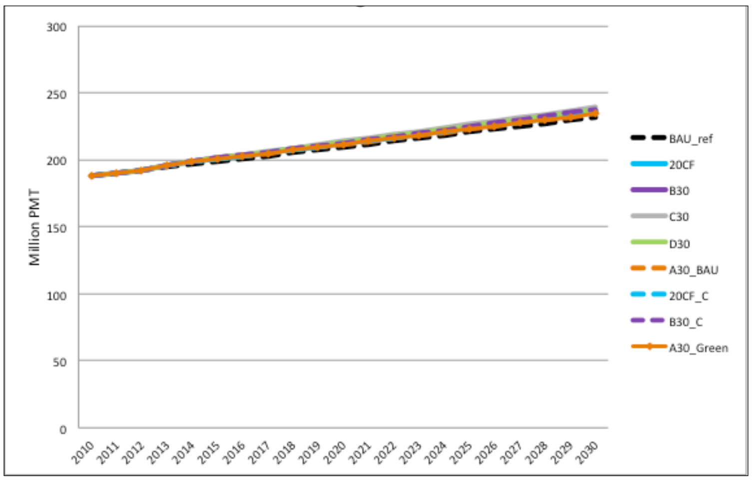


Table 9. Annual transit passenger miles traveled (transit PMT) (billion miles).

Scenario	2015	2020	2025	2030
BAU	*199*	*210*	*221*	*232*
20CF	201	212	224	235
A30_BAU	201	212	223	234
A30_Green	201	212	223	235
B30	201	213	225	237
C30	202	214	227	239
D30	201	213	225	237
20CF_C	201	212	224	236
B30_C	201	213	225	238

Economic benefits relating to transportation substantially improve with new infrastructure

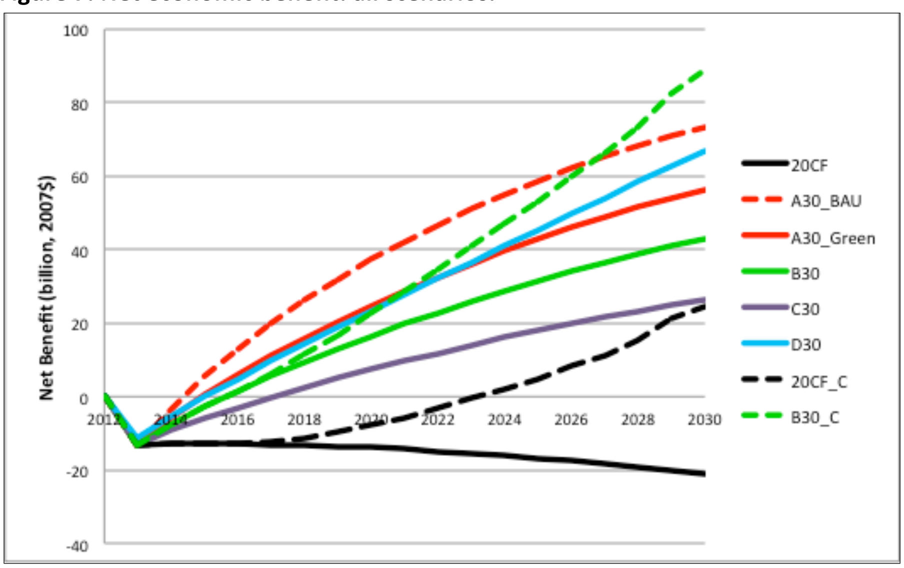
Over the full 2013–2030 time period, net economic benefits related to transportation activity increase between $169 billion and $529 billion with investment scenarios that return $30 billion per year of transportation fuel-generated carbon revenue for green transportation infrastructure investments. The scenario that only implements a carbon fee—with no revenue returned for infrastructure spending—results in a net economic loss of $279 billion in transportation-related costs, although the carbon fee revenue would probably be used for purposes that generate net gains outside the transportation sector. Investing the carbon revenue using current road-centric spending patterns results in net economic gains of

$711 billion. These results show that new infrastructure spending provides potentially large gains in net economic benefits related to transportation activity.

SIMTRAVE calculates net economic benefits as the difference between base case and scenario values of three basic components: utility of households (consumers), production costs (firms), and external effects. Consumers' household utility and firms' production costs make up the vast majority of net economic benefits in the CCPP's model. SIMTRAVE is a partial equilibrium model that simulates the transportation sector in detail, but doesn't include direct links between transportation and other economic sectors or to the labor market.[31] This partial equilibrium design means that net economic benefits relate only to transportation-related costs.

Figure 7 shows that net economic cost in the first year—after the carbon fee is implemented but before any new infrastructure investments have been made—is a loss of about $13 billion. But reinvestment then begins to generate an annual economic gain, and consumers begin to see net benefits in transportation-related costs within two to five years, depending on infrastructure investments. These effects could be relatively significant at early stages with this policy approach: transportation-related net economic benefits for the initial part of these scenarios (2013–2020) range from −$17 to a gain of $59 billion, depending on the type of green infrastructure developed. Without reinvestment in transportation infrastructure, net economic benefits are negative: −$105 billion from 2013 to 2020. Green transportation infrastructure, therefore, provides up to $164 billion more in cumulative benefits from 2013 to 2020 than implementing only a carbon fee.

Figure 7. Net economic benefit: all scenarios.



[31] As a consequence of this partial equilibrium design, the model does not directly enable assessment of the impacts of scenarios on household income levels. The calculation of changes in household utility levels between scenarios is performed under the assumption that overall household income is equal for all scenarios. In basic terms, the utility level reached for each scenario is calculated as a weighted sum of the consumption levels of different transportation goods and services. An increase in utility, therefore, can be the result of a decrease in consumption or a substitution of high-utility goods with low-utility goods. Both of these can be the result of changes in general price structures (either monetary or non-monetary costs) or changes in infrastructure (which affect non-monetary time costs in SIMTRAVE). Similar effects determine the production costs for firms.

Table 10. Annual net economic benefits related to transportation (billion dollars, 2007$).

Year	*BAU*	Carbon Fee	A30 ($ BAU)	A30 (S Green)	B30	C30	D30	*Carbon Fee_C*	*B30_C*
2015	—	–$12.8	$5.6	$0.4	–$2.7	–$5.9	$0.0	–$12.8	–$2.7
2020	—	–$13.9	$37.2	$24.6	$16.4	$7.3	$23.3	–$7.7	$22.7
2025	—	–$16.8	$58.7	$42.8	$31.4	$17.9	$45.4	$4.8	$53.1
2030	—	–$21.1	$73.2	$56.3	$43.1	$26.4	$66.8	$24.6	$88.8

Most of these net economic benefit gains are the result of savings in travel time due to improvements that improve travel conditions and relieve bottlenecks and congestion without inducing new growth in VMT. The differences between which components of transportation costs determine net economic outcomes are also informative. Tables 11a-c and Figures 8 and 9, for example, show how different transportation cost components influence net economic benefits over time. Figure 8 shows transportation-related net economic benefits changes for the carbon fee–only scenario with no reinvestment (scenario "20CF") and Figure 9 shows the effects of reinvesting all revenue in green road infrastructure (scenario "A30"). All cost components for all scenarios are presented in Figure 10 for visual comparison. Each of these graphs shows the different cost component categories in the CCPP's model. They also show, with a green line, the net economic benefit (consumer surplus and producer surplus); with a dashed black line, they show the carbon fee revenue generated from transportation fuels.

As expected, the main negative economic benefit effect is the result of new carbon fee costs. This is the result for every scenario modeled for this report, except new fuel economy standards, which result in higher vehicle purchase and ownership costs. Similarly, the primary positive economic benefit across these scenarios is the gain from time savings related to road travel that occurs when infrastructure is improved, except, again, for scenarios with higher fuel economy requirements, where fuel savings are larger than time savings. This positive time savings effect occurs in all scenarios—even those without new infrastructure investments—and provides a large portion of the economic benefit increases in all scenarios. Nonroad time savings are a significant contributor to economic gains in the scenario that includes freight rail capacity infrastructure improvements.

Table 11a. Components of annual net economic benefit for 2015 (billion 2007$).

Scenario	Carbon Fee	Fuel Cost & Tax	Vehicle Purchase	Other Monetary	Time Cost (Road)	Transit Cost[32]	Time Cost (Nonroad)	*Net Benefits*
BAU	—	—	—	—	—	—	—	—
20CF	–$33.2	$2.3	$8.9	$0.6	$12.5	–$0.7	–$3.2	–$12.8
A30_BAU	–$33.3	$1.1	$4.7	$0.8	$31.0	–$1.0	$2.3	$5.6
A30_Green	–$33.3	$1.5	$5.9	$0.8	$25.8	–$0.9	$0.7	$0.4
B30	–$33.3	$1.7	$6.7	$0.7	$22.7	–$0.9	–$0.2	–$2.7
C30	–$33.3	$1.9	$7.5	$0.7	$19.4	–$0.9	–$1.2	–$5.9
D30	–$33.3	$1.9	$7.5	$0.7	$20.0	–$0.9	$4.0	$0.0
20CF_C	–$33.2	$2.3	$8.9	$0.6	$12.5	–$0.7	–$3.2	–$12.8
B30_C	–$33.3	$1.7	$6.7	$0.7	$22.7	–$0.9	–$0.2	–$2.7

[32] The negative net economic benefit values for shown here for transit actually indicate higher transit use. More transit system use means that more spending occurs for transit activity. Although not reported in this paper, transit costs on a per-mile basis generally decrease as ridership and net economic costs for transit increase.

Table 11b. Components of annual net economic benefit for 2020 (billion 2007$).

Scenario	Carbon Fee	Fuel Cost & Tax	Vehicle Purchase	Other Monetary	Time Cost (Road)	Transit Cost[31]	Time Cost (Nonroad)	*Net Benefits*
BAU	—	—	—	—	—	—	—	—
20CF	–$39.8	$3.7	$11.4	$0.7	$15.4	–$0.8	–$4.4	–$13.9
A30_BAU	–$40.1	–$0.6	–$1.6	–$1.9	$72.2	–$1.9	$11.2	$37.2
A30_Green	–$40.1	$0.5	$1.6	–$1.3	$58.2	–$1.6	$7.3	$24.6
B30	–$40.0	$1.2	$4.1	–$0.9	$48.9	–$1.6	$4.7	$16.4
C30	–$40.0	$2.0	$6.6	–$0.4	$38.8	–$1.6	$1.9	$7.3
D30	–$40.0	$2.2	$6.5	–$0.2	$40.2	–$1.7	$16.2	$23.3
20CF_C	–$39.0	$15.6	$5.5	$0.6	$13.3	–$0.7	–$3.0	–$7.7
B30_C	–$39.2	$13.3	–$1.9	–$1.0	$46.9	–$1.6	$6.2	$22.7

Table 11c. Components of annual net economic benefit for 2030 (billion 2007$).

Scenario	Carbon Fee	Fuel Cost & Tax	Vehicle Purchase	Other Monetary	Time Cost (Road)	Transit Cost[31]	Time Cost (Nonroad)	*Net Benefits*
BAU	—	—	—	—	—	—	—	—
20CF	–$61.6	$5.7	$18.3	$1.2	$24.8	–$1.2	–$8.3	–$21.1
A30_BAU	–$62.6	–$2.8	–$6.4	–$5.6	$132.7	–$3.8	$21.7	$73.2
A30_Green	–$62.4	–$1.2	–$1.8	–$4.5	$113.3	–$3.3	$16.2	$56.3
B30	–$62.2	$0.2	$2.3	–$3.5	$97.9	–$3.3	$11.8	$43.1
C30	–$62.1	$1.8	$7.2	–$2.2	$78.6	–$3.3	-$6.3	$26.4
D30	–$62.0	$2.1	$7.0	–$1.8	$82.1	–$3.8	$43.0	$66.8
20CF_C	–$51.1	$102.2	–$46.1	$0.6	$23.2	–$1.1	–$3.0	$24.6
B30_C	–$51.6	$97.7	–$62.9	–$4.1	$95.7	–$3.3	$17.2	$88.8

Figure 8. Components of net transportation-related economic benefits: scenario 20CF.

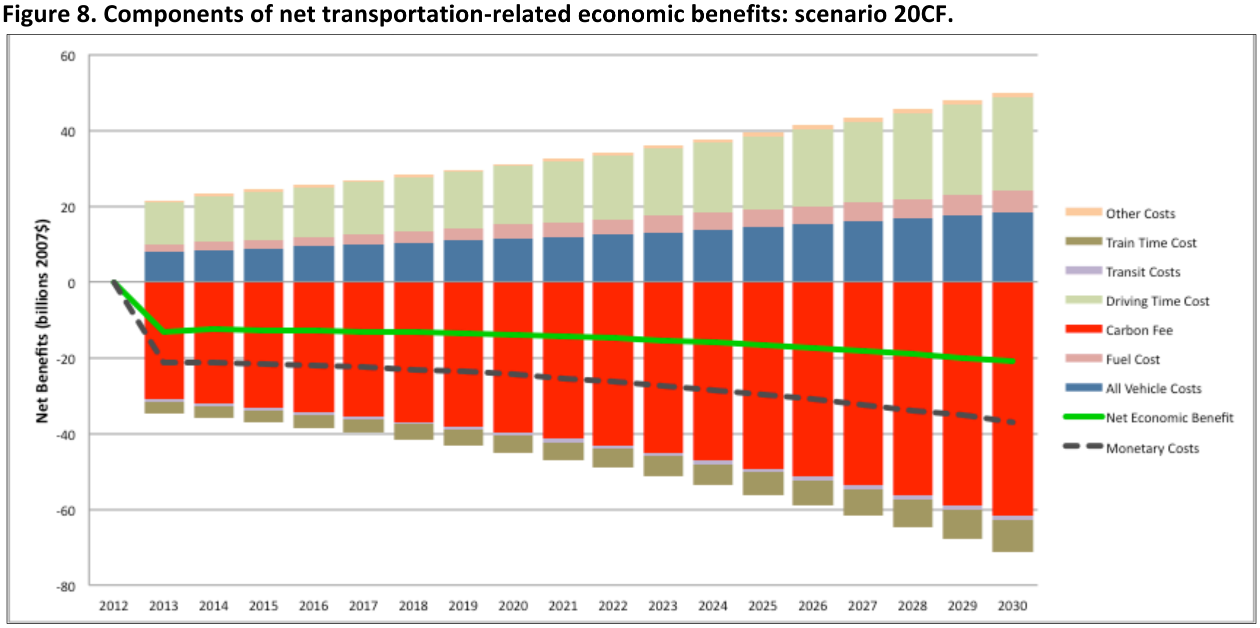


Figure 9. Components of net transportation-related economic benefits: A30_Green (example).

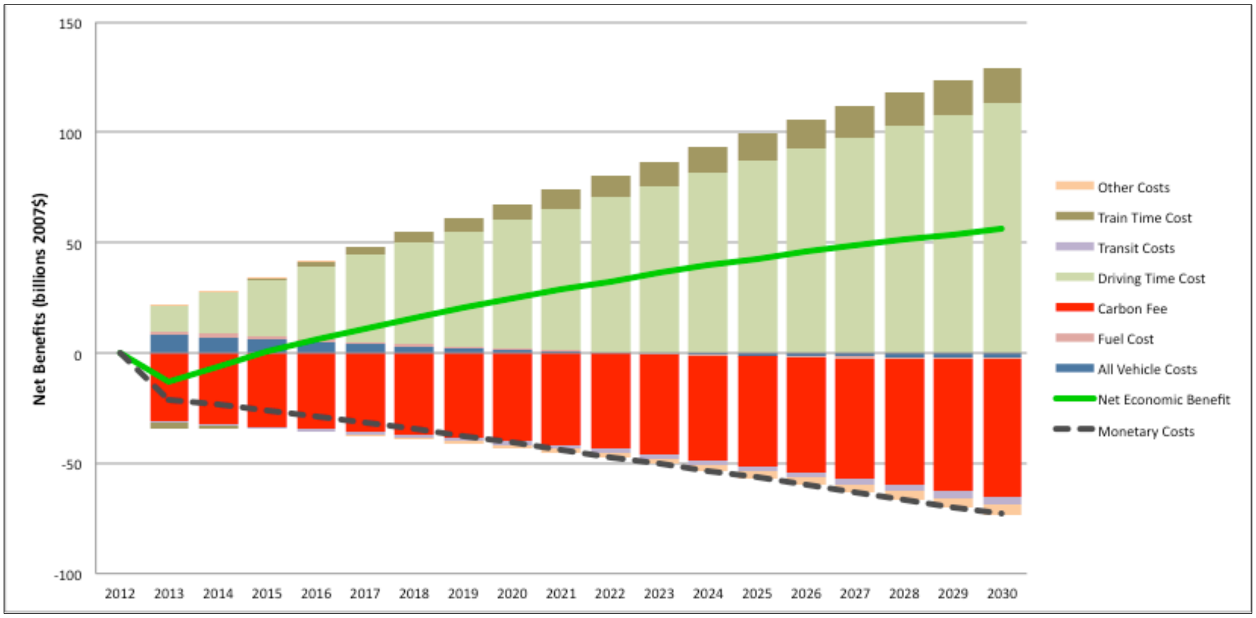


Figure 10. Net economic benefit components for all scenarios.

Another way of comparing the economic benefits effects of transportation infrastructure spending is to examine the rate of return for investment. With total new infrastructure spending from 2013 to 2030 at $510 billion, each dollar spent for the green infrastructure scenarios generates $0.33–$1.04 in transportation-related net economic benefits, and $1.39 for BAU spending patterns. Similar results for the 2013–2020 and 2021–2030 periods are shown in Table 12. During the 2013–2020 period, none of the investment scenarios generate a net rate of return where the economic benefits are higher than the amount spent, but from 2021 to 2030, only one scenario does not generate a rate of return that exceeds the amount spent on infrastructure. This emphasizes the long-term economic benefits from infrastructure investment.

Table 12. Rate of transportation economic benefit generated per dollar infrastructure spending.

	2013–2020			2021–2030			2013–2030 (Entire Period)		
	Spending	Benefit	*Rate*	Spending	Benefit	*Rate*	Spending	Benefit	*Rate*
Carbon Fee	—	–$105	—	—	–$173	—	—	–$279	—
$30b A30_BAU	$210 b	$117	$0.56	$300 b	$593	$1.98	$510 b	$711	$1.39
$30b A30_Green	$210 b	$59	$0.28	$300 b	$436	$1.45	$510 b	$495	$0.97
$30b B30	$210 b	$23	$0.11	$300 b	$322	$1.07	$510 b	$344	$0.67
$30b C30	$210 b	–$17	–$0.08	$300 b	$186	$0.62	$510 b	$169	$0.33
$30b D30	$210 b	$54	$0.26	$300 b	$475	$1.58	$510 b	$529	$1.04
CF + CAFE	—	–$93	—	—	$78	—	—	–$15	—
$30b B30 + CAFE	$210 b	$34	$0.16	$300 b	$575	$1.92	$510 b	$610	$1.20

The general pattern that emerges in Table 12 is that scenarios with more spending for roads have higher rates of economic benefit generation than those with more spent on transit. These estimated benefit returns—$1.39–$0.33 per dollar spent—compare well with previous research (described earlier) that estimated the historic rate of benefit return at $1.10. Table 12 specifically indicates that a dollar spent on green roads results in about $0.97 in transportation-related economic benefit, and a dollar spent on transit results in essentially no net economic benefit.[33] This does not mean that those investments have no value, however: the improved transit provide benefits that are not modeled in the CCPP's SIMTRAVE tool, including equity benefits by improving transportation options for low income households, facilitating land use development patterns that generate lower household vehicle travel[34], etc. These positive effects are hinted at by the trend of transit passenger miles increasing across scenarios. Investment in rail freight system infrastructure appears to have a quick economic benefit effect that also increases over time.

Adding vehicle fuel efficiency requirements achieves significantly greater CO_2 reductions.
To further increase understanding of the potential for transportation sector policies to achieve climate-related goals, we also modeled two scenarios ("20CF_C" and "B30_C") that add increased fuel efficiency standards. Earlier in this report we discussed the potential for using new fuel efficiency standards as a method to reduce emissions while generating net economic benefits. Analyses of recent proposals to increase Corporate Average Fuel Economy (CAFE) standards for motor vehicle years (MY) 2013–2016 concluded that the new regulations will have a net economic benefit of about $9 billion–$35 billion (EPA and NHTSA 2009). Another report estimated that fuel efficiency standards will reduce CO_2 emissions with a net saving of about $95/ton (Vattenfall 2007).

The specific scenarios reported in this paper establish a new requirement that vehicle fuel efficiency requirements increase by 4% per year starting in 2017. Current CAFE standards run through MY 2016, and set an MY2016 average at 34.1 mpg. Vehicle prices also grow to reflect the additional technology

[33] The amount of net economic benefit generated by a dollar of transit spending cannot be confidently estimated with the scenarios reported here, but the change in results implies a near-zero effect or even a slight loss in net transportation benefits from transit spending. This implication can be made by comparing the rate of decrease in economic benefits between scenarios and the difference in spending between scenarios; between scenario A30 and C30, highway spending decreases 50% and transit spending increases from zero to 50%, and cumulative economic benefits (2013–2030) also decreased by about 50%.
[34] These types of effects can be addressed by the SIMTRAVE model structure, but require detailed data to model results with disaggregated population segments or different urban land use types. These are anticipated for a future version of SIMTRAVE.

costs that result from higher fuel economy requirements. Figure 11 shows the scenario average fuel economy standards compared to the baseline BAU fuel economy standards used in the main scenarios of this report. New vehicle technologies or fuel types (such as electric vehicles) are not specified in these results, but are implied as a means for manufacturers to meet the higher fuel efficiency requirements.

Figure 11. Fuel economy: BAU and all scenarios.

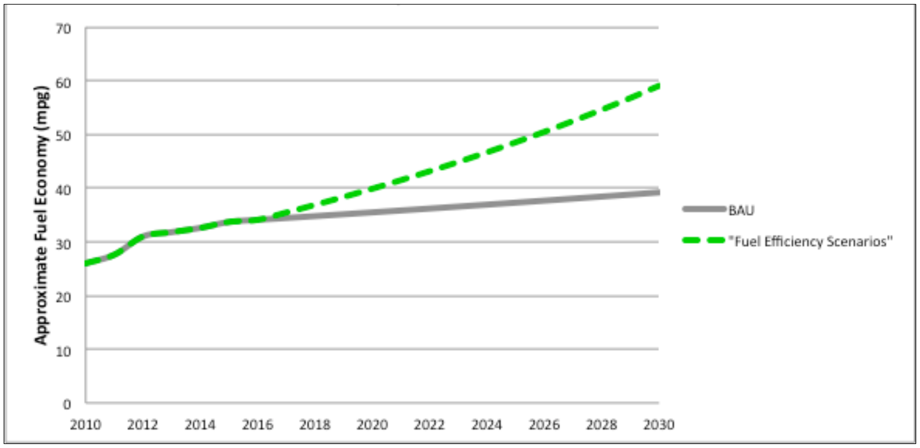


Figure 12. Example car price with 4% fuel efficiency increase.

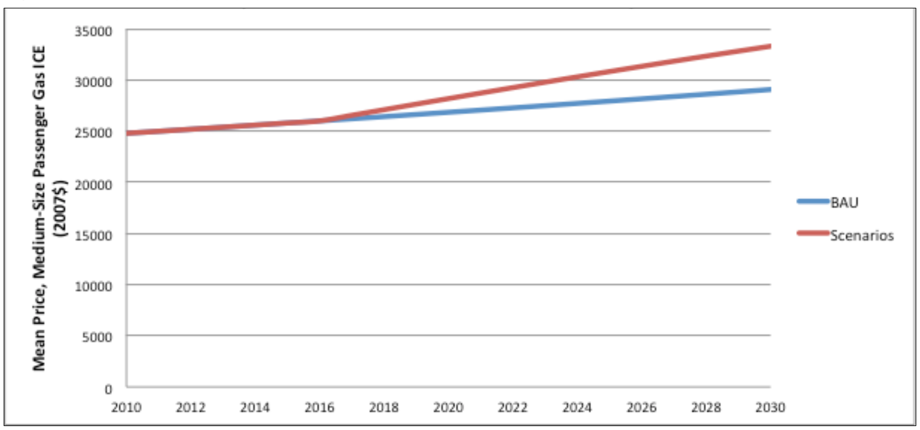


Figure 12 shows how a typical vehicle price would increase as fuel efficiency requirements are implemented. This additional cost varies between vehicle types, but averages 8% by 2020 and 28% in 2030. The cost is amortized over the life of the vehicle and converted to a per-mile basis, which then affects travel activity. The net effect is that higher vehicle costs slightly reduce total travel activity because vehicle costs are higher.[35]

But the primary mechanism through which increased fuel efficiency requirements reduce emissions is by lowering the fuel consumed for each mile of vehicle travel. This effect is significant: the 4% annual efficiency increase results in a total of about 1,300 Mt abated CO_2 emissions. This effect is a smaller

[35] This net result includes the rebound effect of people purchasing smaller, less expensive cars. All vehicle prices increase to meet the new fuel efficiency requirements; for purchasers of smaller cars who would have otherwise purchased larger cars, the amortized per-mile vehicle cost may be lower or higher than the cost would have been if they had purchased a larger car, depending on the type of vehicle they choose to purchase. For consumers who would have already bought a smaller car, their amortized prices are also higher. The net effect of higher prices reducing travel activity is the aggregate across all vehicle types and purchases.

percentage of emission reductions than increased fuel efficiency: by 2030, the fuel efficiency for road vehicles has been increased in these scenarios by 73%, but annual emissions are just 17%–18% lower (see Figure 13).

Figure 13. Transportation on-road emissions (fuel economy comparison).

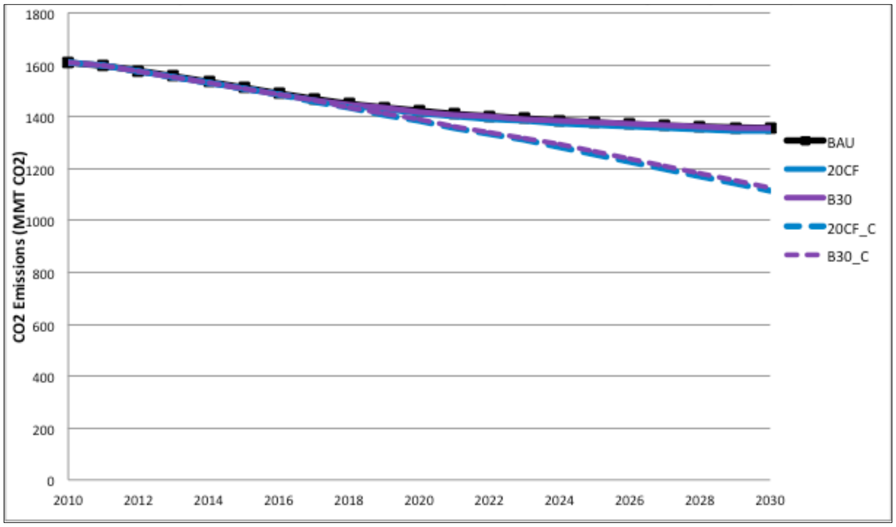


Table 13 shows the cumulative changes in key measures for two scenarios that add higher fuel efficiency standards, and compare those results to the equivalent scenarios without new requirements.

Table 13. Cumulative changes in key measures (2013–2030) for fuel efficiency scenarios.

Scenario	CO_2 emissions	Road VMT	Private Vehicle PMT	Transit PMT	Economic Benefit (Transportation)
Units of measure	*(Mt)*	*(billion VMT)*	*(billion PMT)*	*(billion PMT)*	*($ billion, 2007$)*
BAU reference *(baseline values)*	*(25,665)*	*(65,276)*	*(85,134)*	*(3,833)*	—
Carbon fee (20CF)	−172	−566	−724	48	−$279
CF + 4% annual Fuel Eff. increase	−1,504	−571	−777	50	−$15
B30	−46	−160	−185	66	$344
B30 + Fuel Eff. increase	−1,392	−164	−239	68	$610

With the general policy scenario of this report and new fuel efficiency requirements starting in 2017 (continuing the current prescribed basic improvement rate for 2013–2016), cumulative CO_2 emissions from 2013 to 2020 would decrease between 96 and 120 Mt (about 1.0% of business as usual). Over the entire 2013–2030 period, cumulative emissions would decrease between 1,392 and 1,504 Mt (about 5.5% of BAU). These cumulative emissions abatement are much larger than with scenarios that don't improve fuel efficiency; for the 2013–2030 period, adding new fuel efficiency requirements increases CO_2 emissions abatement by 9 to 30 times over scenarios without new fuel economy standards.

Higher fuel efficiency standards also result in lower amounts of total transportation activity (VMT and total PMT) change from the comparable scenarios in this report, shown in Figure 14. These relatively small annual differences are the expected net effects of higher per-mile vehicle technology costs. Table 14 shows the absolute and percent differences at five-year intervals.

Figure 14. Passenger miles traveled (PMT), all modes (CAFE scenario comparisons).

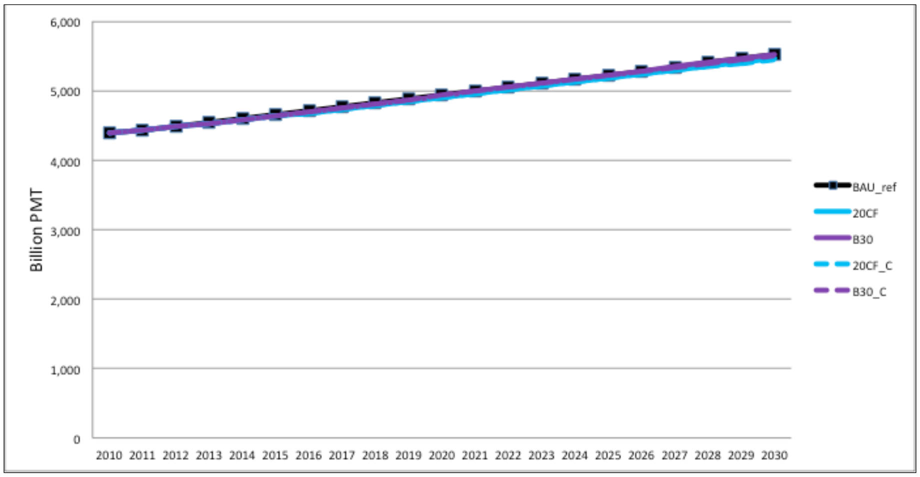
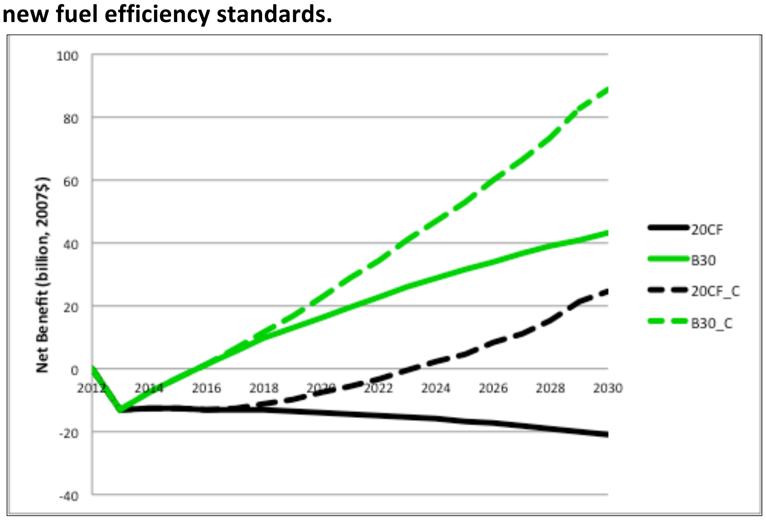


Table 14. Annual passenger miles traveled (PMT) (trillion miles).

Scenario	2015	2020	2025	2030
BAU	*4.66*	*4.94*	*5.22*	*5.52*
20CF	4.63	4.90	5.18	5.47
20CF_C	4.63	4.90	5.18	5.45
B30	4.64	4.93	5.22	5.53
B30_C	4.64	4.93	5.22	5.51

Figure 15, by comparison, shows how transportation-related net economic benefits noticeably change when the costs of higher fuel economy standards are incorporated into policy scenarios. The net annual economic benefit is about $50 billion higher in 2030 (with a cumulative increase from 2017 to 2030 of about $250 billion). This effect mostly reflects lower fuel consumption, because the costs of equivalent scenario pairs (scenario without new fuel economy standards paired with an equivalent scenario with new standards) begins to diverge in 2017 when the more stringent standards begin, and the primary difference is vehicle purchase and associated costs. This suggests that a 4% increase in fuel efficiency requirements would generate about $400 billion in economic benefit gains.

Figure 15. Total transportation-related net economic benefits with new fuel efficiency standards.



The overall conclusion that can be drawn is that policies requiring higher vehicle fuel efficiency will have a much larger magnitude of effect for abating CO_2 emissions, and do so while also generating significantly higher net economic benefits and reducing total travel more than the equivalent scenarios without higher fuel efficiency standards.

DISCUSSION OF RESULTS

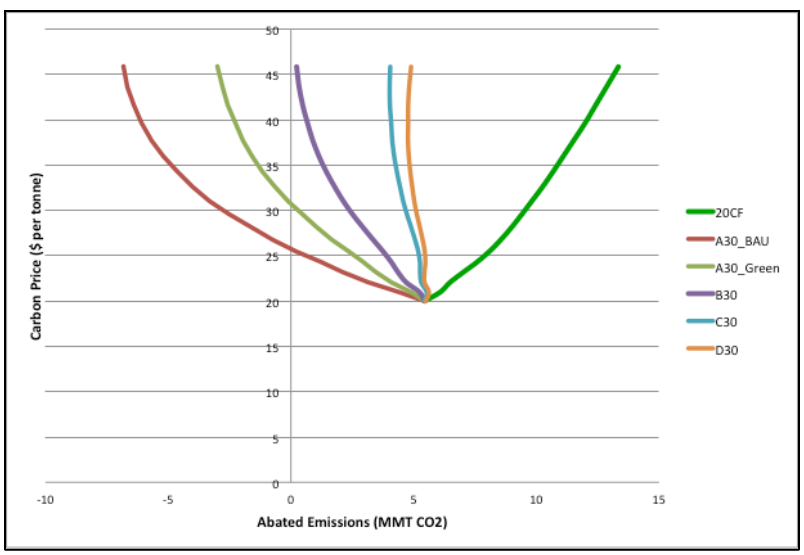
The main quantitative results of the scenarios indicate that a carbon fee by itself does not result in a large decrease in transportation GHG emissions. Targeted reinvestment of carbon fee revenues in infrastructure improvements can, however, lead to significant increases in transportation-related net economic benefits and still achieve small decreases in GHG emissions.

This is not an unexpected result, but it is new: previous research on related topics has not been able to answer the specific question of whether the policy approach modeled for this report would generate a climate policy windfall by reducing emissions, or whether it would instead wipe out climate policy objectives by increasing transportation activity and emissions.

Because different transportation policies have varying effectiveness for transportation, climate, and economic effects, developing and implementing different strategy combinations can be an effective way to achieve diverse desired policy outcomes.

A key consideration for policymakers is the cost of abating GHG emissions. In 2013, the carbon price on transportation fuels is \$20/ton, and in 2030 the price is about \$46/ton. The abatement curves in Figure 16 show how the two scenarios that invest all funds in roads have no abatement effect after a few years, and there is only minimal emission abatement, regardless of carbon price, in the remaining scenarios with infrastructure spending. By 2030, only the carbon fee without infrastructure reinvestment scenario results in carbon abatement greater than the initial carbon price-induced effect. The effect of the carbon fee is completely wiped out in all other scenarios for the period up to 2030, although the abatement begins to increase as infrastructure investment continues in the later years. By improving travel conditions, the ***infrastructure investment reduces or completely eliminates the per-mile cost that the carbon fee imposes.*** Although this effect decreases as the carbon fee grows, only a couple of spending scenarios appear likely to eventually result in abatement.

Figure 16. Carbon abatement costs with different infrastructure investments.

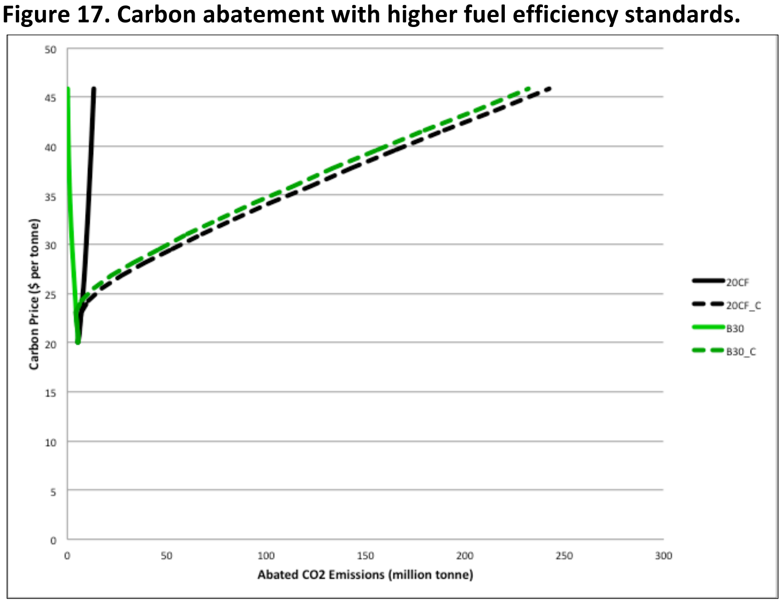


These abatement curves in Figure 16 also reveal how policy design for an approach that generates revenue from transportation fuels and then reinvests at least a portion of those funds in transportation infrastructure can achieve different levels of abatement. A primary reason that emissions after infrastructure spending do not exceed the baseline BAU emissions for some scenarios is that they occur after the reduction in emissions triggered by the carbon fee on transportation fuels. If that fee were low enough, it would no longer send a sufficient price signal to generate abatement in excess of the emissions rebound that occurs with new infrastructure. Similarly, a higher carbon fee would send a price signal sufficient to still achieve net abatement for the two scenarios with road investment. This report does not examine at what the price that effect would occur, but there can be little doubt that calibrating the correct carbon fee should be an important part of implementing this basic policy framework.

In addition to showing the importance of setting the fee to meet policy goals, these scenarios and the abatement curves in Figure 16 show that the amount of CO_2 emissions abated varies based on how the funds are invested. This means that different levels of spending would also achieve varying levels of abatement. Careful policy design would be needed to calibrate the appropriate spending levels to meet desired outcomes: spending too much or too little may alter the amount of emissions, the amount of transportation activity, or the net economic benefits.

The additional reduction that occurs when higher fuel efficiency requirements are added is potentially an important signal about the significant opportunities that complementary policies can play to achieve climate goals—emissions reductions—from the transportation sector. Figure 17 shows how a complementary policy tool—in this case, higher fuel efficiency standards—can achieve significantly larger reductions than scenarios without. All the scenarios in Figure 16 (those without new fuel economy standards) would be closely grouped on the left side of the Figure 17 chart, while abatement with higher fuel efficiency requirements is shown by the curves that extend to the right. Total abatement with higher fuel efficiency requirements is about 30 Mt/year higher in 2020 than for those scenarios without, although the carbon fee is the same (~$28/ton or $0.25/gallon gasoline). In 2030, abatement with higher fuel efficiency standards is about 230 Mt/year higher than for scenarios without (carbon fee ~$46/ton or $0.40/gallon gasoline).

Figure 17. Carbon abatement with higher fuel efficiency standards.



Further, Table 15 shows that the use of a complementary policy can potentially achieve GHG emissions at relatively high per-ton net economic benefits, or even—specifically with higher fuel efficiency standards—reduce emissions with a larger per-ton net economic benefit than comparable scenarios without new fuel efficiency standards.

Table 15. Net economic benefits for CO_2 emissions with higher CAFE requirements (dollar/ton).

Scenario	2020			2030			Cumulative Benefit
	Emissions	Benefit	Benefit/ton	Emissions	Benefit	Benefit/ton	(2013–2017)
20CF	1,415	–$13.9	–$9.8	1,343	–$21.1	–$15.7	–$10.9/ton
20CF + CAFE	1,384	–$7.7	–$5.6	1,114	$24.6	$22.1	–$0.6/ton
B30	1,421	$16.4	$11.5	1,357	$43.1	$31.8	$13.4/ton
B30 + CAFE	1,390	$22.7	$16.3	1,125	$88.8	$78.9	$25.1/ton
A30_BAU	1,425	$37.2	$26.1	1,364	$73.2	$53.7	$27.7/ton
A30_Green	1,423	$24.6	$17.3	1,360	$56.3	$41.4	$19.3/ton
C30	1,419	$7.3	$5.1	1,353	$26.4	$19.5	$6.6/ton
D30	1,418	$28.3	$20.0	1,352	$66.8	$49.4	$20.7/ton

A common technique for describing the mechanisms available for reducing emissions from transportation is to present them as a three-legged stool, where each component must be addressed to reduce emissions. The three "legs" are travel activity, carbon intensity of fuel, and vehicle fuel efficiency. The main policy scenarios for this report all focus on the travel activity leg: the carbon fee on transportation fuels reduces transportation activity by making it slightly more expensive, while the new infrastructure makes travel slightly easier (i.e., cheaper), which encourages transportation activity. The two additional scenarios that add stricter fuel efficiency standards affect another leg of the stool: vehicle fuel efficiency. This report concludes that requiring higher fuel efficiency standards can achieve emissions reductions 9 to 30 times larger than equivalent investment scenarios. Other policies can address the carbon intensity of transportation fuels.

Linking some type of carbon fee[36] on transportation fuels with green infrastructure spending can be done without wiping out any policy gains. The ***effectiveness of using carbon revenue to fund transportation infrastructure has limits for both policy arenas***, although it does achieve some appealing climate and transportation outcomes. Policymakers and stakeholders interested in linking climate and transportation policies should consider these significant conclusions from this report:

- A carbon fee by itself does not result in a large decrease in transportation GHG emissions. Targeted reinvestment of carbon fee revenues in infrastructure improvements can, however, lead to significant increases in transportation-related economic benefits and still achieve moderate decreases in GHG emissions. The economic gains from infrastructure reinvestment are large enough to make otherwise negative economic transportation policies achieve positive net economic benefits.
- An ***opportunity for synergy between the climate and transportation policy arenas exists by targeting new spending on infrastructure likely to support lower emissions:*** higher spending for maintenance, bottleneck relief, transit, etc. Although these are more likely to achieve transportation policy goals than climate goals, they do so with a less negative impact on climate goals.
- Effective application of ***transportation policy as climate policy will require using policy tools beyond a carbon price and targeted "green" infrastructure investments.*** The price signal sent by a relatively small increase in fuel costs is not sufficient to significantly reduce transportation emissions. Other policy tools might include higher fuel efficiency requirements, long-term planning and land use

[36] It should be noted that these results are not limited only to a carbon fee–based revenue source, but would apply to behavioral changes with any per-gallon fuel-based fee or tax equivalent to $20 per metric ton of CO_2, with the same $30 billion per year spent on transportation infrastructure.

standards, and a variety of additional pricing mechanisms. Revenue from a carbon fee could potentially help offset additional costs.

- From a climate policy perspective, the ***opportunity to achieve emissions reductions from higher fuel efficiency standards is attractive.*** New fuel economy requirements (a 4% annual increase starting in 2017)[37] generates substantially more CO_2 reductions than any price or infrastructure scenarios. When combined with a higher fuel price that funds new infrastructure, higher CAFE standards can also achieve significant net economic benefits.

A large range of additional transportation policies can achieve emissions reductions if designed and implemented to do so (USDOT 2010). This report examines only the narrow question of whether transportation infrastructure spending reinforces or wipes out GHG emissions reductions that result from a carbon fee on transportation. ***The bottom line conclusion is that it is possible to develop a policy that combines a carbon fee on transportation fuels with an investment regime in transportation infrastructure that serves both climate policy goals of reducing GHG emissions and improving transportation conditions and economic benefits.***

The Climate Change Policy Partnership's SIMTRAVE model enables the simulation of complex transportation policies and resulting direct effects, such as emissions and travel activity, as well as indirect effects, such as net economic benefits. This report does not examine how complementary policies other than higher CAFE standards would affect the basic conclusion, but future reports from the CCPP will examine additional complementary and combined policy scenarios that integrate climate and transportation policy objectives to increase understanding of how these two policy arenas interact and further explore how transportation policies can also serve as effective climate policies. ***As policymakers consider how to combine transportation and climate policy in the most effective manner possible, the type of integrated analysis of potential policies and outcomes for key measures should provide insights that can help develop effective and efficient approaches.***

[37] On September 30, 2010, the National Highway Safety Administration (NHTSA) and Environmental Protection Agency (EPA) released a preliminary proposal (Notice of Intent to Issue a Proposed Rulemaking) to increase Corporate Average Fuel Economy (CAFE) standards by 3%–6% per year from 2017 to 2025. The 4% fuel efficiency increase modeled for this report was prepared prior to that release, but is comparable in fuel efficiency and vehicle costs to the NHTSA/EPA 4% proposal.

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