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Policies to Decarbonize Transportation

Implications of Carbon Pricing and Complementary Actions that Advance Technology in the Transportation Sector

By Jennifer Macedonia

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Introduction and summary

On November 4, 2016, the Paris Agreement entered into force after the United States and nearly 200 other countries agreed to decarbonize the global economy by the second half of the century. The main purpose of the agreement is to strengthen the global response to the threat of climate change, with the goal of keeping global temperature rise below 2 degrees Celsius compared with preindustrial times while pursuing efforts to limit any increase to 1.5 degrees.[1] According to the United States and other major economies, achieving this goal will require developed countries to reduce their emissions 80 percent or more by 2050.[2]

Critical to any successful decarbonization plan is an effective and timely strategy to unleash the innovation and infrastructure deployment needed to achieve significant greenhouse gas emissions reductions in the transportation sector. In 2016, transportation became the United States' highest carbon dioxide-emitting energy consumption sector.[3] The U.S. midcentury decarbonization strategy projects that the country's transportation sector would require an 86 percent reduction in fleetwide emissions intensity levels from 2015 to meet decarbonization goals.[4]

Countries, states, and localities around the world are using and considering carbon pricing policies as a means of reducing the greenhouse gas emissions that significantly contribute to climate change. According to mainstream economic theory, if markets work well and carbon is priced at appropriate levels, the resulting price signals should be the most efficient and cost-effective means of reducing such emissions from a variety of human activities, including burning fossil fuels in ground transportation. An efficient carbon pricing program would provide a long-term price signal that is predictable, economywide, and of sufficient escalating strength to both drive the most cost-effective greenhouse gas reductions in the near term and motivate the innovation and transformation needed to reach longer-term goals.

For several reasons, however, the transportation sector may not be as responsive to economywide carbon pricing as the electricity sector. The same carbon price that would effectively drive action in the power sector would provide a much weaker signal for transportation. This is because the carbon price would represent only a small portion of the total cost of driving a vehicle—about 2 percent of the per-mile cost at a carbon price of $30 per ton and a gasoline price of $2.14 per gallon—and may not be appropriately factored into consumer and manufacturer decisions.

The most important emissions reduction opportunities for ground transportation include a large-scale shift from petroleum-fueled vehicles to zero-emitting technologies, such as electric-drive vehicles.[5] While there has been significant development in battery technology and electric vehicles in recent years, penetration of electric vehicles into the fleet has not been as significant as deployment of renewable energy in the power sector.[6] Just as it has taken time for wind and solar energy technology to build up manufacturing scale in order to reach a point of steep cost declines, transformation of the transportation sector will require time to ramp up manufacturing scale, bring down the cost of alternatives, overcome consumer misconceptions, and deploy new infrastructure.

Because in the near term there are opportunities to achieve significant reductions at lower costs—particularly in the power sector—it may be challenging for policymakers to establish a carbon price high enough to send the signals needed to decarbonize the transportation sector. For these reasons, companies, consumers, and governments may delay the shorter-term investments needed to lay the groundwork for realizing transformation in the transportation sector long enough to threaten the ability to reach scientifically driven decarbonization goals.

If implemented, carbon pricing would give consumers a signal to drive fewer miles and to choose lower-emitting means of transport, as long as reasonable alternatives exist. For the reasons mentioned above and described further in this report, however, the signal is likely to be too weak to drive the economies of scale and innovation critical to ensuring that consumers have a realistic means to respond to carbon pricing.

Thus, the continued use of policies that push technological advancement, in combination with approaches that create a demand-pull for cleaner technologies, is important for ensuring that the transportation sector has the tools available to reach aggressive midcentury climate goals.

Technology-push, also known as technology-forcing, policies for ground transportation include:

- Continued use of vehicle standards that spur manufacturers to drive down emissions intensity and produce cleaner vehicles
- Continued investment in research, development, demonstration, and deployment to bring promising innovations—such as lower-cost and longer-range electric vehicles—into the marketplace
- Investment in the charging stations and other infrastructure needed to support wide-scale adoption of transformative zero-emission options

Demand-pull policies include carbon pricing, either in the form of a fee or in the form of a cap-and-trade program.

This report looks at specific policies to decarbonize transportation, with a focus on technology-push vehicle standards and demand-pull carbon pricing approaches. It also examines the impact of carbon pricing on the power sector and the challenges it would face in ground transport.

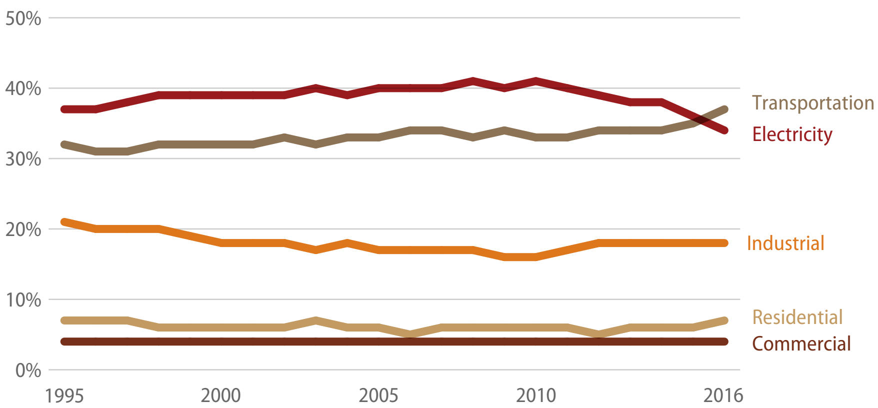
Transportation must play a role in any decarbonization strategy

Transportation, including passenger vehicles, is a major source of carbon dioxide emissions in the United States, contributing 37 percent of the total energy-related carbon dioxide, or CO2, emitted in 2016.[7] Furthermore, transportation has grown in importance for climate change mitigation in recent years. As retiring coal-fired power plants reduced the carbon footprint of U.S. electricity production and lower gasoline prices spurred increased vehicle travel, transportation overtook electricity production in the first seven months of 2016 to become the highest CO2-emitting sector in the United States. (see Figure 1)

FIGURE 1

Share of U.S. energy-related carbon dioxide emissions, by sector

In 2016, the transportation sector overtook electricity as the largest source of U.S. energy-related carbon dioxide emissions



Note: Data for 2016 only include the first seven months of the year. The emissions from the electricity sector are not included in the total for each of the other end-use sectors.

Source: Energy Information Administration, *Monthly Energy Review: July 2016* (U.S. Department of Energy, 2016), available at https://www.eia.gov/totalenergy/data/monthly/archive/00351607.pdf.

Road transport is particularly important for climate change mitigation as it accounts for more than one-quarter of all U.S. greenhouse gas emissions. Cars and light-duty trucks are responsible for more than 60 percent of the carbon dioxide emitted from transportation.[8]

Significant progress has been made thus far to improve the emissions performance of internal combustion engine vehicles and the cost and practicality of alternative vehicles and fuels. However, decarbonizing ground transportation will require significantly more aggressive reduction strategies focused on a move away from carbon-emitting fuels such as gasoline and diesel toward vehicles and other transport modes that are electrified or fueled by hydrogen and carbon-neutral alternatives. It will also require efforts to minimize vehicle miles traveled—for example, through telework and greater reliance on mass transit.

Given the transportation sector's importance, an effective plan to address climate change must not ignore or delay transformative innovation and infrastructure deployment in order to set the stage for deep decarbonization.

Policies to decarbonize transportation

The urgency of addressing climate change and the time required for innovation and infrastructure replacements justify the consideration of a two-pronged approach, which includes both technology-push and demand-pull features for transportation policy. This report describes the strengths and weaknesses of these two types of policy approaches and explains why a combined approach holds promise for transportation.

Complementary technology-push and demand-pull policies are needed

Compared with either on their own, a two-pronged approach that implements carbon pricing in combination with vehicle standards and/or other technology-forcing policies and investments has greater potential to spark needed innovation. It also has a greater chance of reducing CO2 emissions in the transportation sector by influencing consumer choices about transportation mode, vehicle purchase, and miles driven.

Vehicle standards and policies to promote zero-emission vehicles have been successful at incentivizing manufacturers to innovate and prioritize the carbon footprint of the vehicles they produce. But they do not push drivers to drive less and may not convince consumers to buy the most efficient and lowest-emitting vehicles. As long as reasonable alternatives exist, carbon pricing should both encourage consumers to buy lower-emitting vehicles and send them a signal to drive fewer miles. As discussed in the following sections, however, carbon pricing would struggle to offer a strong enough signal for the transformative innovation that the transportation sector needs.

Some analysts argue that layered policies are inefficient and lead to higher costs.[9] While it is important to understand the interactions and potential downsides of implementing policies in combination, it is also critical to appreciate the real-world factors that may affect the ability of carbon pricing on its own to transform the transportation sector in a timely way. Each of these factors is described in the following subsections.

Particularly if gasoline and carbon are moderately priced, the continued use of successful vehicle standards and other technology-forcing policies—such as feebates, which reward efficiency by levying charges on inefficient vehicle models—is warranted to bridge the transition to broad adoption of advanced transportation technologies.[10]

A 2010 report from Resources for the Future argues that vehicle standards may help create the environment necessary for the development and adoption of vehicle technologies with high upfront costs and long-term payoffs.[11] While a carbon price would also provide incentives for innovation, vehicle standards have the advantage of eliminating the risks to innovators of fuel price volatility that may dampen the price signal for manufacturers to create vehicles with better fuel economy and lower CO2 emissions.[12] Greater technological progress will lower the cost of decarbonization.

Meaningful vehicle standards in combination with moderate carbon pricing may be more politically practical than strong carbon pricing. For example, drivers appear less opposed to standards than taxes, which involve revenue transfer to the government.[13] In addition, carbon pricing tends to be moderately regressive, since energy costs are a larger percentage of income in lower-income households.[14] In contrast, vehicle standards tend be progressive—increasing costs for higher-income families especially—as they raise the cost of new vehicles.[15]

Thus, a pragmatic approach to decarbonizing ground transportation would promote innovation through vehicle standards and investment in research, development, demonstration, and deployment, as well as encourage more efficient use of transportation through a phase-in of carbon pricing.

Experience with vehicle standards and policies

Historically, fuel economy standards have proven to be an effective policy to improve the efficiency and reduce the energy consumption of passenger vehicles. Requiring vehicle manufacturers to either meet increasing fleetwide fuel economy standards or face fines has driven a 50 percent increase in average new vehicle mpg performance in the United States since 1980.[16]

U.S. light-duty car and truck fuel economy and greenhouse gas tailpipe standards for model years 2017 through 2025 are projected to result in an average industry fuel economy of 54.5 mpg.[17] They are also expected to reduce the average CO2 emission rate of vehicles sold in the United States by 34 percent.[18] These current standards are already proving successful: Model year 2015 fuel economy is at a record high average of 24.8 mpg, and CO2 emissions are at a record low average of 358 grams per mile.[19]

Other technology-forcing policies have also shown success at increasing the market share of alternative vehicle technologies. California's Zero Emission Vehicle, or ZEV, program was originally adopted in 1990 and updated in 2012 to require 1.5 million ZEVs—about 15 percent of new vehicle sales—on California's roadways by 2025.[20] ZEVs include battery, plug-in hybrid, and hydrogen fuel cell electric vehicles. California's ZEV program led to the state achieving an electric vehicle market share more than double that of the rest of the United States in 2014.[21] Since 2012, nine states—Connecticut, Maryland, Maine, Massachusetts, New Jersey, New York, Oregon, Rhode Island, and Vermont—have adopted California's standards and set a collective target of 3.3 million ZEVs sold in participating states.[22]

However, with low gasoline prices and fuel economy improvements across all types of vehicles, the cost of driving has gone down and consumers are driving more.[23] In addition, consumers have fewer reasons to choose more efficient vehicle types, and higher-emitting trucks have increased their share of new vehicle purchases.[24]

Thus, while technology-push policies are important for creating the environment needed for transformative innovation, they do not fully capture all opportunities to reduce emissions, such as driving fewer miles, using zero-emitting vehicles or mass transit, and carpooling. In turn, they are less effective without the complement of a demand-pull policy such as a carbon fee or cap-and-trade program.

Theory versus reality: Carbon pricing as a signal to reduce CO2 emissions in the transportation sector

Carbon pricing, which associates a cost with emissions, creates incentives for emitters to reduce their emissions—and to continuously seek better, faster, and cheaper ways of doing so. Roughly 40 national jurisdictions and more than 20 cities, states, and regions are currently pricing about 12 percent of global greenhouse gas emissions.[25]

Two different forms of carbon pricing, a carbon fee and emissions trading, offer technology-neutral ways to send a price signal to consumers to value zero- and low-emitting means of satisfying their energy and product needs. Generally, a carbon tax provides price certainty by establishing a fixed fee of dollars per ton of carbon dioxide, while emissions trading provides certainty regarding the level of reductions by establishing a cap on the amount of allowable pollution. Both forms of carbon pricing may be designed to phase in over time by either increasing the fee owed per ton of carbon dioxide or decreasing the allowable tons of CO2 emissions. (See text box)

Policies are most effective at achieving an environmental goal when they provide incentives across the breadth of possible emissions reduction options, including existing technologies, innovations, operational and behavioral measures, and demand reduction. Both forms of carbon pricing have the potential to achieve this by applying a consistent economywide price on carbon to incentivize the full range of reduction opportunities across emitting sectors.

How a carbon fee works

A carbon fee, or tax, is an explicit form of carbon pricing where a fee is collected for each ton of CO2 emitted by affected sources. A carbon fee serves as an incentive for consumers and companies to shift away from higher-emitting fossil fuels to low- or zero-emitting alternatives and to improve the energy efficiency of the vehicles, products, and services that the carbon fee affects.

For transportation, because the amount of CO2 produced from the combustion of fossil fuels is directly linked to the fuel's carbon content, the fee could be calculated and applied at various points in the fuel chain, including upstream at extraction or distribution points or downstream at the pump. Regardless of where in the chain the fee is exacted, the additional cost will typically be passed on to the consumer—for example, the driver—and exert a push toward lower-emitting options, such as fewer trips, a more fuel-efficient car, or public transit.

How cap and trade works

A CO2 cap-and-trade program is an implicit form of carbon pricing because the effect of the policy is to increase the cost of affected activities—such as burning fossil fuels—in direct proportion to their emissions of carbon dioxide. Under such a program, a limit is set on the total level of pollution, and permits or allowances are issued for each ton of carbon dioxide allowed under the cap.

At the end of each compliance period, affected facilities must surrender an allowance for each ton of carbon dioxide they emit. Owners obligated by the program may choose to either invest in CO2 reductions on their own or invest in enough allowances from the market to continue to emit at previous levels, with the understanding that investments elsewhere will reduce CO2 emissions enough to free up allowances at a cost.

When markets function well and carbon is appropriately priced

Most economists agree that if markets function well and carbon is appropriately priced, then a carbon pricing approach should be the most efficient and cost-effective means of achieving CO2 reduction across the group of emissions sources that the approach would cover.[26] In theory, carbon pricing should be more cost-effective than regulation due to its potential to exploit more opportunities. For example, carbon pricing addresses both vehicle design and miles driven, while vehicle standards focus only on vehicle design.

Additionally, environmental economics indicates that a carbon fee should be set to reflect the approximate environmental damages to society. Emissions sources causing the same damage, such as CO2 emissions from different types of vehicles, should be taxed or implicitly priced at the same rate.[27] For example, the U.S. government has estimated the social cost of carbon for regulatory cost-benefit analyses at $36 in 2015, $42 by 2020, and $50 by 2030.[28]

With respect to carbon pricing for the transportation sector, a number of factors can be expected to prevent markets from functioning well and carbon from being priced at the appropriate level. Specifically, as the next subsections will explore in more detail, the impact of carbon pricing is just a small percentage of the cost of driving and may not be appropriately valued by consumers and, thus, manufacturers.

In addition, given political pressures to keep prices low, it would be challenging for carbon pricing alone to catalyze the level of research, development, demonstration, and deployment of low- and zero-carbon technologies and infrastructure at the scale needed to reach midcentury goals.

Targeted policies need to complement carbon pricing where market impediments prevent people from adequately responding to carbon price signals, as is likely to be the case with transportation.[29]

Economywide pricing produces a weak signal for transportation

Under a carbon pricing approach, each dollar per metric ton of CO2 would increase the price of a gallon of gasoline by only about 1 cent. Thus, if a carbon fee or allowance price of $30 per ton of CO2 were passed on to drivers filling their gas tanks, they would see a carbon price signal amounting to an extra 30 cents per gallon.[30] A carbon price of $30 per ton of CO2 amounts to a price signal of only 0.9 cents to 1.5 cents per mile, depending on the type of car or sport utility vehicle driven.[31]

Given that fuel cost is only a fraction of the total cost of owning and operating a vehicle, an additional carbon price of 30 cents per gallon represents a relatively weak signal to drive consumer and manufacturer behavior. Factoring in all vehicle-related expenses for an average vehicle, at a gasoline price of $2.14 per gallon, fuel costs make up about 10 cents per mile, or 15 percent of the total cost per mile to drive; a $30-per-ton carbon price would amount to 2 percent of the total per mile cost of driving.[32] (see Figure 2)

FIGURE 2

Breakdown of vehicle-related expenses with a $30-per-ton carbon price

A $30 carbon price would add only 1 cent per mile to the cost of driving

Note: Chart includes cost for ownership of a large sedan with 20.6 miles per gallon and traveling 15,000 miles per year.

Sources: American Automobile Association, "Your Driving Costs: How much are you really paying to drive?" (2016), available at http://publicaffairsresources.aaa.biz/wp-content/uploads/2016/03/2016-YDC-Brochure.pdf; Energy Information Administration, *Annual Energy Outlook 2016* (U.S. Department of Energy, 2016), available at http://www.eia.gov/outlooks/aeo/.

Challenges to influencing consumer behavior on transportation

On the consumer side, there are two types of transportation decisions that can affect CO_2 emissions: long-term decisions, such as which type of vehicle to buy or whether to live near public transportation, and short-term decisions, such as whether to take a particular trip.

In a comprehensive review of the economic literature, researcher David Greene concluded that the rational economic model of consumer behavior that economists typically use may not adequately describe consumer decision-making about fuel economy in the real world.[33] While consumers care about fuel costs and value fuel economy when fuel prices are high, there is evidence that consumer responses to changes in fuel price are significantly more complex than economic assumptions would suggest.[34]

It is not clear that consumers appropriately value future fuel costs, particularly at the points in time when it would make the most difference. For example, the time frame in which people have the most ability to affect the carbon dioxide they will produce over the next decade from ground transportation is during major decisions, including buying a car, choosing a residence, or taking a job. Because a carbon price from transportation would be such a small portion of the overall financial equation, however, it is unlikely to factor into such major decisions. In most cases, once those big decisions have been made, there are fewer opportunities for individuals to influence the carbon footprint of their transportation needs. Unless public transit is an option, the need to commute to work is likely to supersede any price signal that the average person may experience to reduce vehicle miles traveled. Because the daily commute is a baseline requirement for many, the amount of money spent on gasoline has less of an influence on daily miles driven; previous larger life decisions—such as choosing a job, car, or home—have locked in for some time the lifestyle patterns that affect transportation emissions the most.

Additionally, the average consumer may not have the correct information about the interaction of future fuel prices and a vehicle's fuel economy or about the benefits or perceived drawbacks of alternative technologies. For example, electric vehicles have faced serious consumer adoption issues, including range anxiety, high up-front costs, and consumer misconceptions. This contributed to available U.S. models of electric vehicles averaging fewer than 5,000 sales each in 2014.[35]

In a transportation study, Tom Turrentine, Kenneth Kurani, and Rusty Heffner interviewed a number of subjects about vehicle purchase decisions and found:

> *Most households confessed to having no idea of their fuel costs over any period of time—weekly, monthly, or annually. They did not budget, manage, or track fuel costs in any systematic way. … Even households with high financial skills struggled to guess what improvements in fuel economy were worth to them in dollars and cents.*[36]

The Fuels Institute looked at the relationship between vehicle purchases and fuel prices and determined that consumers do look at fuel prices and fuel economy but not as a primary consideration.[37] As a result, the institute found that fuel prices have little influence over a typical consumer's decision on what type of vehicle—whether a sedan, minivan, or sport utility vehicle—to purchase.

These findings are consistent with the fact that fuel costs are a small fraction of the cost of buying and operating a vehicle and suggest that a modest carbon price alone is unlikely to be a key driver of vehicle purchase decisions.

Given the political divisiveness over policies to address climate change, consumer uncertainty over the durability and future levels of carbon pricing could further limit carbon pricing's influence on decisions, such as vehicle purchases, that require a long-term cost-benefit accounting to justify the added cost of a lower-emitting alternative.

Carbon prices are also not likely to have a significant impact on short-term driving decisions. As Turrentine and his co-authors found, most drivers did not pay close attention to fuel expenditures. Further, the researchers found that some respondents' "lack of attention to gas costs was due to the fact that they felt they couldn't do anything about it; they had to drive as much as they did to lead the lives they had constructed for themselves."[38] This is consistent with economic analysis that shows that the short-term elasticities—the change in the amount of a product a consumer buys when the price increases—are significantly smaller than the long-term elasticities.

Historical gas price trends provide insight on the impact that carbon pricing may have on the transportation sector. Because there have been significant changes in gas prices over the years, it is possible to look at key parameters that affect CO2 emissions; vehicle miles traveled, or VMT; and purchase decisions. The combined impact of these decisions can be seen in gasoline consumption trends.

The Congressional Budget Office, or CBO, examined this issue and noted that research suggests that a 10 percent increase in gasoline prices—equivalent to a carbon price of $30 per ton at a gas price of $3 per gallon—leads to a roughly 0.6 percent decrease in gasoline consumption in the short term.[39] In the longer term, that same increase in fuel price would result in a 4 percent decrease in gasoline use. Further, the CBO's analysis looked at underlying factors that contribute to short-term reductions in gasoline use—which VMT significantly affects—and found the results consistent with the 0.6 percent reduction in VMT for every 10 percent increase in the price of gas. The CBO study focused on the period from 2003 to 2007, when gasoline prices doubled from around $1.50 per gallon to $3 per gallon. Consistent with expectations, there was a decline in market share for light-duty trucks, from 55 percent to 52 percent.

If those trends hold, and a $30-per-ton carbon price achieves CO2 reductions in the range of 0.6 percent to 4 percent for the transportation sector, such a policy would fall far short of the Paris Agreement's midcentury decarbonization goals.

Some economists suggest that a carbon price may induce a stronger change in fuel consumption and vehicle purchase decisions than a similar fuel price increase.[40] They attribute this to both the media coverage and public attention surrounding carbon pricing implementation and the consumer belief that tax changes are more persistent than other gasoline price changes. Nonetheless, even a somewhat enhanced response to a moderate carbon tax is expected to be insufficient to meet the task at hand.

Limitations to delivering a clear price signal to manufacturers

The United States' market-based society operates around a fundamental theory of supply and demand, which suggests that if there is enough consumer demand for low-emitting vehicles, manufacturers will innovate to provide those vehicles to the market. Without a policy push, however, manufacturers have shown that they are unlikely to prioritize the fuel economy and greenhouse gas emissions of their vehicles if they do not trust that their consumers will do so.

Unlike a technology standard, a carbon tax creates an incentive to find multiple ways of reducing CO2 emissions and should, therefore, lead to a broader range of innovations.[41] However, there is evidence that a carbon price on its own, while effective for incentivizing incremental innovation, is unlikely to produce the transformative innovation required to dramatically reduce CO2 emissions from the transportation sector.

It takes time and money to develop and advance technologies as well as to bring down their costs to compete with conventional vehicles. As researcher Joshua Meltzer describes, innovation is an iterative, complex process, and a variety of market failures have been found to lead to the private sector's underinvestment in research and development.[42] Meltzer concludes that the development of green technologies will require a range of technology-push and demand-pull policies to address barriers to innovation. Technology-push measures—such as vehicle standards—drive the supply of innovative vehicles, while demand-pull measures—such as carbon pricing—reduce consumer demand for less-efficient vehicles by increasing their cost.[43]

The World Energy Council projects that achievement of the Paris Agreement goals would require 100 million electric cars on the road by 2030, up from the 2015 level of 1.26 million.[44] But a small increase—such as 30 cents more per gallon—in fuel cost from carbon pricing would provide a weak signal for the large capital infrastructure investments that would be required to expand deployment of alternative vehicle technologies.

Given the political pressures to keep carbon pricing low and the difficulties in delivering a clear price signal in the transportation sector, a carbon pricing policy alone likely would not be able to drive the level of transformation needed in the required time frame.

Impacts of carbon pricing on the road transportation and electricity sectors

The dynamics in the transportation sector are different than in the power sector, where zero-carbon alternatives are at or near parity with conventional fossil fuel-fired generation.[45] An identical carbon cost will have a much greater impact on the cost of a fossil fuel power plant than it will on the cost of driving. Thus, a carbon price will provide a much stronger signal to consumers to choose lower-carbon options for generating electricity than it will for transportation.

Modeling of economywide carbon pricing demonstrates the weak impact expected for the transportation sector. For example, in an analysis of the Waxman-Markey economywide cap-and-trade bill, the Environmental Protection Agency projected the contribution that each sector would make toward the total reductions.[46] The analysis forecasted that the largest source of emissions reductions would come from the electricity sector, while transportation sector emissions would barely change.

Different fuel types produce different amounts of carbon dioxide when burned to produce energy, and the quantity of carbon dioxide created from burning a fuel is a function of that fuel's carbon content. Coal has a significantly higher carbon content than gasoline and nearly twice the carbon content of natural gas. When burned in an average vehicle, gasoline emits, per mile, half of the carbon dioxide produced per kilowatt-hour, or kWh, from a coal-fired power plant. It also emits just slightly more than the carbon dioxide produced per kWh from a new advanced natural gas combined cycle, or NGCC, generator. (see Table 1)

Because of the other costs involved, however, the same carbon price would make up a very different share of the total cost of owning and operating a vehicle versus a power plant. For example, a $30-per-ton CO2 price amounts to just 2 percent of the total cost of an average vehicle, compared with 16 percent of the cost of a new advanced natural-gas-fired power plant and 44 percent of the cost of an average existing coal-fired power plant. (see Table 1)

TABLE 1

Carbon pricing as a share of the cost of owning and operating vehicles and power plants

A $30-per-ton carbon price amounts to 44 percent of the total cost of operating a coal-fired power plant vs. just 2 percent of the cost of owning and operating a gasoline vehicle

		Gasoline vehicle	New advanced NGCC power plant	Existing bituminous coal-fired power plant
Cost without a carbon price		69.9 cents per mile	5.58 cents per KWh	3.9 cents per KWh
Carbon dioxide emissions		0.0005 ton per mile	0.0004 ton per KWh	0.001 ton per KWh
Carbon dioxide costs	at $10 per ton	0.5 cent per mile	0.4 cent per KWh	1 cent per KWh
	at $30 per ton	1.4 cents per mile	1.1 cents per KWh	3.1 cents per KWh
	at $50 per ton	2.4 cents per mile	1.8 cents per KWh	5.2 cents per KWh
Share of cost from a $30-per-ton carbon price		**2%**	**16%**	**44%**

Sources: Vehicle data: American Automobile Association, "Your Driving Costs: How much are you really paying to drive?" (2016), available at http://publicaffairsresources.aaa.biz/wp-content/uploads/2016/03/2016-YDC-Brochure.pdf. Based on a large sedan traveling 15,000 miles per year.
Power plant data: The levelized cost of electricity, or LCOE, value for new advanced NGCC units entering service in 2022 is taken from the U.S. Energy Information Administration's Annual Energy Outlook reference case, which makes predictions based on laws and final regulations and includes a capacity-weighted average based on projected capacity additions across the 22 U.S. regions of the National Energy Modeling System. The LCOE is a "summary measure of the overall competitiveness of different generating technologies" and "represents the per-kilowatt-hour cost (in real dollars) of building and operating a generating plant over an assumed financial life and duty cycle. Key inputs to calculating LCOE include capital costs, fuel costs, fixed and variable operating and maintenance (O&M) costs, financing costs, and an assumed utilization rate for each plant type." See Energy Information Administration, Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2016 (U.S. Department of Energy, 2016), available at http://www.eia.gov/outlooks/aeo/pdf/electricity_generation.pdf. Total cost to operate an existing coal-fired power plant is based on the average power plant expenses in 2014 for major U.S. investor-owned electric utilities, weighted by net generation. See Energy Information Administration, Electric Power Annual 2014 (U.S. Department of Energy, 2016), Table 8.4, available at http://www.eia.gov/electricity/annual/archive/03482014.pdf.

The same carbon price would have considerably more influence on the economics of renewable electricity compared with alternative vehicle technologies. Even without a carbon fee, the average levelized cost of wind power—5.85 cents per kWh—is very close to the levelized cost of new natural gas—5.58 cents per kWh.[47] Factoring in a carbon price, the levelized price of wind would be competitive with existing coal-fired generation at a carbon price of less than $30 per ton.

It is worth noting that, while today's prices suggest that a carbon price alone could significantly reduce power sector emissions, other policies have played a role in reaching this point. The prices of land-based wind and solar have dropped more than 90 percent since 1980, and technology-forcing standards such as state renewable programs and tax incentives have been a key reason for these declines. As recently as 2010, wind would not have been competitive with new natural gas- or existing coal-fired power plants, even with a carbon price of $30 per ton. For solar, the turning point has been even more recent.[48]

Clearly, there are differences between today's electricity and ground transportation sectors. These include the percent of total cost that a carbon price would represent and the ability of a carbon price to both overcome market barriers and bridge the gap between conventional and advanced technologies. In the power sector, zero-emitting alternatives have reached a tipping point of wide-scale and rapidly increasing adoption. While zero-emitting transportation options may be poised to achieve a similar trajectory of deployment in the coming decades, they are not as far along in their evolution.[49] A transformation of the automobile market will require persistent effort to reach manufacturing scale and the right balance of government policy, infrastructure, and consumer support.[50] These differences and similarities between the power and ground transportation sectors help explain the importance that vehicle standards will continue to play for some time, even if carbon pricing is adopted.

Conclusion

An economywide carbon pricing mechanism, whether in the form of a carbon tax or cap and trade, is likely to be the cornerstone of any comprehensive greenhouse gas reduction plan. Nonetheless, there is reason to doubt that a pricing policy alone will put the United States on the technology trajectory to achieve the reductions necessary to decarbonize its transportation sector in the time frame that scientists deem necessary to avoid catastrophic climatic change.

Analyses of economywide carbon pricing mechanisms generally agree that such policies are likely to have their most significant impact on the power sector, where a broad range of low- and zero-emitting technologies are already being deployed on a widespread basis. Therefore, policymakers must combine carbon pricing with other efforts in the transportation sector. Just as other policies—including state renewable and energy efficiency standards and tax credits—have been successful at driving down the price of zero-carbon electricity,[51] technology-forcing policies such as vehicle standards are needed to continue to drive the commercialization of low- and zero-emitting transportation options.

About the author

Jennifer Macedonia, at the time of writing this report, was a principal consultant at JLM Environmental Consulting. She has more than twenty years of experience in energy and environmental policy, as well as expertise in market-based instruments to spur technological innovation. As an independent consultant focusing on the nexus of policy, engineering, and economics, Macedonia advised clients on strategy and policies for the power, transportation, and industrial sectors. As a senior advisor and fellow at the Bipartisan Policy Center, Macedonia led economic analysis and advised states on designing effective policies to address the challenges of modernizing the power sector. At the U.S. Environmental Protection Agency, Macedonia served as a market-based policy expert on the U.S. delegation to international climate negotiations and helped shape market-based programs to reduce air pollution, including the acid rain sulfur dioxide trading program.

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Endnotes

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