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Vehicle Electrification: Coordinating Transportation and Power Sector Policies to Maximize Air Quality Benefits

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Key Question

- How can companion power sector pollution policies maximize and fairly distribute air quality benefits from vehicle electrification?

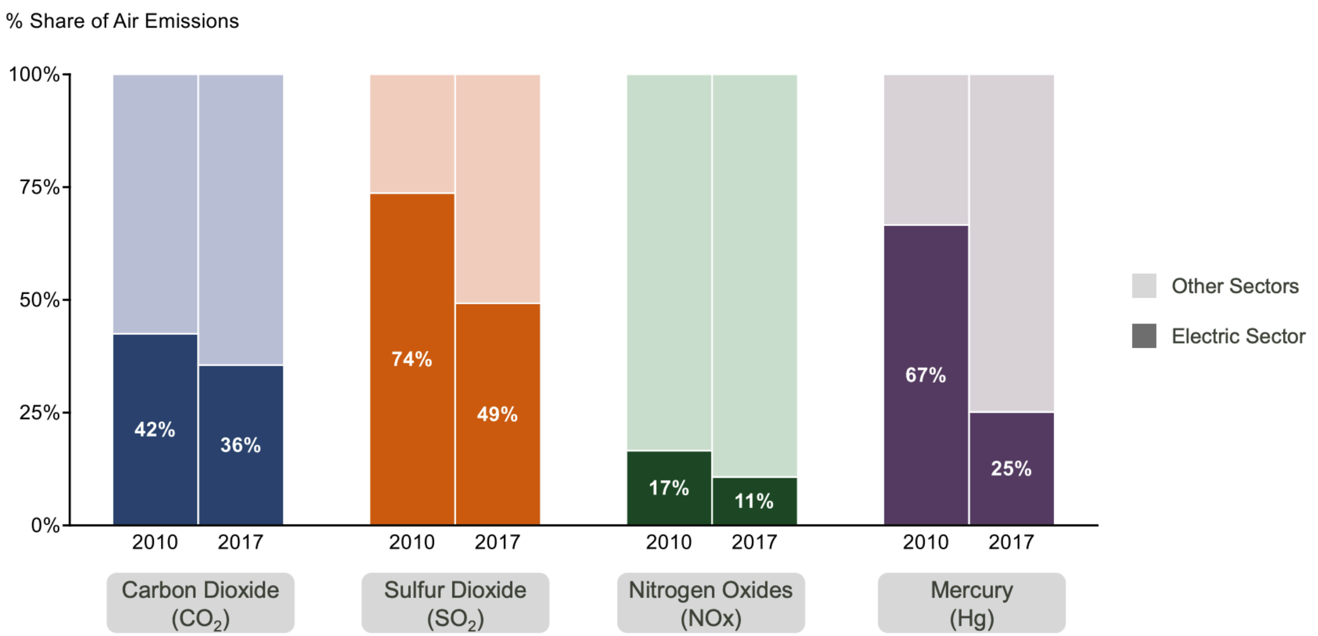
This policy brief looks at the likely electricity demand from projections of personal electric vehicle uptake in the United States, and then suggests power sector policies to ensure reductions in air pollution from this sector even while demand increases from transportation.

INTRODUCTION

Electricity transformed the American economy, dispelling darkness, powering our manufacturing base, and improving lives. Power production has also generated a significant supply of air pollution, harming human health, injuring crops, and warming the earth's atmosphere.

Since the 1970s, state and federal agencies have taken action to curb smog, soot, and other pollution from the power sector, with remarkable success. Just in the last decade, the share of pollution in the United States generated by the power sector has dropped precipitously (Fig. 1).

Fig. 1. Share of Emissions: U.S. Electric Sector and Other Sectors



Source: U.S. Environmental Protection Agency. Air Emissions Inventory for Criteria Air Pollutants (March 2019). TRI National Analysis (October 2018).

However, further reductions are needed in the power sector and across the economy. Most notably, science indicates we need to cut worldwide emissions of greenhouse gases like carbon dioxide (CO_2) 80% from 2005 levels by mid-century to avoid catastrophic climate change.[1] The most promising pathway for the United States is to decarbonize the power sector while electrifying other sectors such as transportation, building space/water heating and cooling, and heavy industry.[2] This strategy leverages the power sector momentum depicted in Figure 1, and shrinks the number of carbon emitting sources in the U.S., potentially by orders of magnitude. Federal carbon regulation has sputtered, but other federal and state policies and tax incentives have nudged grid de-carbonization, primarily through displacement of coal-fired power plants by natural gas and renewables generation. State policies and corporate sustainability goals continue to pressure the power sector to become cleaner, including through the integration of renewables.

[1] See, e.g., IPCC, 2018: Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above preindustrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [V. Masson-Delmotte, P. Zhai, H. O. Pörtner, et al., eds.].

[2] See, e.g, D. Steinberg et al., Electrification & Decarbonization: Exploring U.S. Energy Use and Greenhouse Gas Emissions in Scenarios with Widespread Electrification and Power Sector Decarbonization, NREL Technical Report, NREL/TP-6A20-68214 (July 2017); M. Miotti, G.J. Supran, E.J. Kim and J.E. Trancik, Personal Vehicles Evaluated Against Climate Change Mitigation Targets, Envt'l Science & Tech. (Sept. 27, 2016).

Meanwhile, to reduce air pollution from cars, states are purchasing electric fleets for government use, funding charging infrastructure, and enticing first movers with tax incentives.

Coordination of these policies will be important. A small rebound in energy sector greenhouse gas emissions in 2018—resulting from an increase in transportation emissions and natural gas generation to meet new electricity demand—shows that while further progress is possible, it is not inevitable.[3] Electrification of new sectors of the economy will increase demand for electricity. Depending on where the power sector is in its decarbonization trajectory (which will differ across regions of the country), this increased demand could throw a lifeline to older and more polluting fossil fuel (or nuclear) units, drive the construction of new natural gas plants, or facilitate the integration of renewables. Moreover, new demand may occur at different times of day. Managing when that demand hits the grid could avoid expensive fossil fuel infrastructure build-out to meet new peak capacity, whether by shifting load to low-demand times, or matching new demand with variable renewable resources. Finally, air quality models and monitoring are needed to project and confirm climate and air quality benefits from electrification.

While the power and transportation sectors emit significant amounts of many air pollutants, this policy brief focuses on CO_2 and NOx as a way to capture important dynamics in the power sector. Natural gas eclipsed coal as the top source of electricity generation in 2015.[4] Traditional natural gas plants emit 59 percent of the CO_2 and 65 percent of the NOx emitted by a coal plant producing the same amount of electricity; combined cycle gas plants emit 46 percent of the CO_2 and just 7 percent of the NOx of that coal plant.[5] As a result, the shift from coal to gas generation has driven down these emissions. And yet, natural gas combustion remains a large source of CO_2 and NOx pollution.[6] Further deployment of nonemitting and net-zero sources of electricity are needed to meet midcentury decarbonization goals and national air quality standards. Tracking CO_2 and NOx emissions maintains focus on these larger goals. Moreover, because NOx pollution is localized, tracking it ensures all communities experience improved air quality. Sulfur dioxide (SO_2) is also important to monitor; because transportation is a less significant source of this pollutant, it is critical to ensure that electrification does not drive net-SO_2 increases.

Part I of this policy brief provides a brief history of regulating CO_2, NOx, and SO_2 from power plants. It describes power sector emissions trends, and by contrast presents emissions trends in transportation. Part II summarizes Nicholas Institute modeling that studies how the incremental increase in power demand from electric vehicles could be met under different future scenarios.

Part III suggests policies to deploy alongside a vehicle electrification strategy, to maximize air quality benefits. This list is not exhaustive and is meant to stimulate further discussion. Policies fit four categories: reducing emissions in the power sector (green); reducing emissions in the transportation sector other than through an electrification focus (orange); shifting energy demand to optimal times of day (purple); and monitoring air quality benefits (red).

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[3] Trevor Hauser, Hannah Pitt, and Hannah Hess, Final US Emissions Estimates for 2018 (May 31, 2019).

[4] U.S. EIA, EIA forecasts natural gas to remain primary energy source for electricity generation (Jan. 22, 2018) (providing charts indicating the shares of each fuel in electricity generation since 2006).

[5] J.A. de Gouw, D.D. Parrish, G.J. Frost, M. Trainer, Reduced emissions of CO2, NOx, and SO2 from U.S. power plants owing to switch from coal to natural gas with combined cycle technology, Earth's Future (Feb 21, 2014); Mark Z. Jacobsen, Evaluation of Coal and Natural Gas with Carbon Capture as Proposed Solutions to Global Warming, Air Pollution, and Energy Security, 100% Clean, Renewable Energy & Storage for Everything, Cambridge University Press (forthcoming). However, methane emissions from natural gas supply systems may eat into this net climate benefit. Stefan Schwietzke, W. Michael Griffin, H. Scott Matthews, and Lori MP Bruhwiler, Natural gas fugitive emissions rates constrained by global atmospheric methane and ethane. Environmental Science & Technology, 48:14 (June 27, 2014), 7714–7722.

[6] In 2018, natural gas fired power plants emitted about one-third of the power sector's CO2 pollution, or 581 million metric tons. U.S. EIA, Frequently Asked Questions: How much of U.S. carbon dioxide emissions are associated with electricity generation?. The natural gas value chain also releases methane, a potent greenhouse gas.

EV COMPANION POLICIES FOR STATES TO CONSIDER

States will have different points of entry into this discussion. Some states wonder whether a declining CO_2 cap on the power sector can accommodate new demand from electric vehicles (EVs). For others, it's a timing question—when should states encourage electrification, given what remains to be done to decarbonize the power sector. Meanwhile, states leveraging Volkswagen dollars[7] to spur electrification[8] want to ensure air quality benefits from these efforts. This paper suggests that policies tackling air pollution from each sector must be implemented with the other in mind, to achieve the most cost-effective and healthy outcomes.

PART I: BACKGROUND

Since enactment of the 1970 Clean Air Act, states and the U.S. Environmental Protection Agency (EPA) have sought to reduce NOx[9] and SO_2[10] pollution from power plants by extending the height of smokestacks, requiring plants to install controls or meet numeric pollution standards, and setting state or sector-wide pollution caps.

More recently, regulators have used some of these approaches to reduce power sector CO_2 emissions. Beginning in 2011, the EPA and the states began writing greenhouse gas conditions into permits for new and modified "major" sources of pollution, including power plants.[11] In 2015, the EPA finalized a rule to require new fossil units to meet a CO_2 rate based on the use of carbon capture and sequestration.[12] The agency also finalized the Clean Power Plan (CPP), a rule setting statewide CO_2 caps for existing power plants, based on efficiency upgrades and shifts to cleaner generation sources. In 2019, the EPA replaced the CPP with a less ambitious rule,

[7] In 2016–17, the U.S. settled Clean Air Act claims that Volkswagen AG ("VW") installed "defeat devices" on cars to cheat federal emissions tests. VW paid $3 billion to states and tribes, including for EV charging infrastructure.

[8] For instance, at least 23 states have joined agreements to coordinate on regional EV infrastructure planning, education, and outreach efforts. See, e.g., Regional Electric Vehicle Plan for the West. See also, Drive Electric Tennessee, A Roadmap for Electric Vehicles in Tennessee (2019).

[9] Nitrogen dioxide contributes to algae blooms in coastal waters, and NO2 and NOx-driven ozone reduce visibility, trigger asthma and other respiratory diseases, and form acid rain which kills trees and aquatic life.

[10] Sulfur dioxide can cause damage to the lungs, contribute to particulate matter emissions, and cause acid rain.

[11] See, e.g., U.S. EPA, PSD and Title V Permitting Guidance for Greenhouse Gases (March 2011); Memorandum from Janet G. McCabe and Cynthia Giles to EPA Regional Administrators, Next Steps and Preliminary Views on the Application of Clean Air Act Permitting Programs to Greenhouse Gases Following the Supreme Court's Decision in Utility Air Regulatory Group v. Environmental Protection Agency (July 24, 2014).

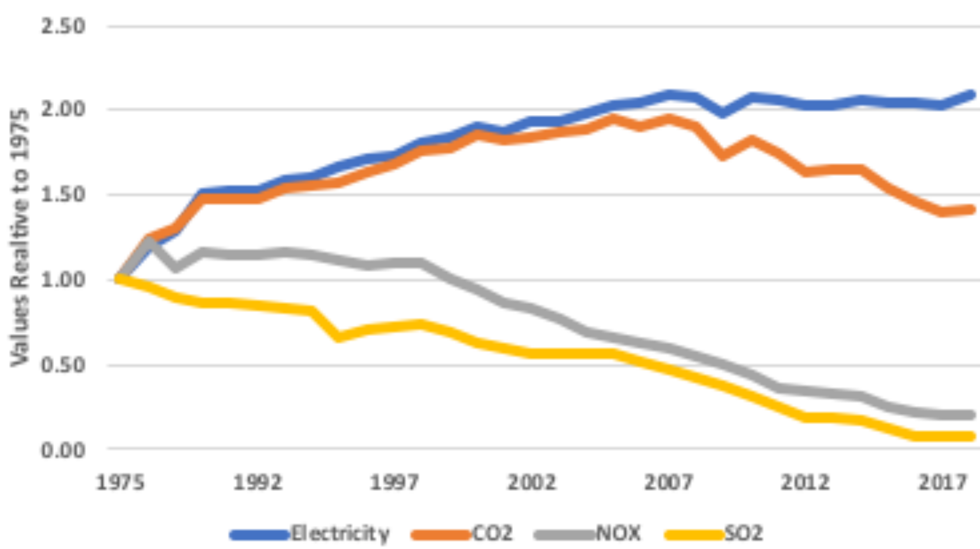
[12] In 2018, the U.S. EPA proposed to revise this standard, to instead base it on the performance of "the most efficient demonstrated steam cycle in combination with the best operating practices." 83 Fed. Reg. 65424 (Dec. 20, 2018).

limited to efficiency upgrades at coal plants. Meanwhile, at the state level, some regions of the country have continued to impose power sector emissions caps—and more are being contemplated.

From 1990, when Congress enacted the Acid Rain Program,[13] to 2018, the sector experienced an 84 percent drop in NOx and a 92 percent drop in SO2 emissions. The sector's CO2 emissions have also fallen, though more modestly (about 4 percent). These drops occurred despite an increase in electricity demand over most of that time period (Fig. 2), because of pollution standards, clean energy policies, and innovation. Breakthroughs in NOx pollution control technology, natural gas production, and the manufacture of solar and wind power components have upended settled expectations. America is bending the curve on power sector emissions, through energy efficiency and displacement of coal-fired power plants by natural gas and renewable generation.

In 2019, a growing number of cities, states, and corporations are committing to cut greenhouse gases 80 percent below 2005 levels by 2050. Twelve states have laws on the books capping CO2 emissions from the power sector (California has an economy-wide cap). Twenty-nine states and the District of Columbia have renewable portfolio standards, requiring utilities to purchase electricity from solar, wind, and other renewable resources; another eight states have nonbinding clean energy goals. But as suggested by 2018 emissions data, without additional policies or market breakthroughs and if demand increases, progress in the power sector could stall.

Figure 2. U.S. Electricity and Emissions over Time[14]



Meanwhile, transportation emissions are on the rise. Carbon dioxide emissions from this sector grew from 1469.1 million metric tons (MMt) in 1990, to 1800.6 in 2017. NOx emissions have dropped, reflecting improvements in fuel efficiency and tailpipe standards,[15] but remain high. due to travel volume. Vehicle miles traveled (VMT) have increased more than 150 percent, from 2.12 trillion miles in 1990 to 3.21 trillion miles in 2018.[16] Car ownership rates (0.766 per person; 1.968 per household) have not rebounded to prerecession highs

[13] Section 407 of the Acid Rain Program directed EPA to set NOx limits for coal-fired units (achievable through the installation of "low-NOx" burners). Subsequently, EPA imposed several regional NOx caps on the power sector.
[14] Based on data from the U.S. Energy Information Administration. Credit: Tim L. Johnson, Associate Professor of the Practice in Energy and the Environment, Duke University Nicholas School of the Environment.
[15] U.S. EPA, The Benefits and Costs of the Clean Air Act from 1990 to 2020, Final Report – Rev. A (April 2011), at Table 2-4 (identifying the tailpipe standards and reformulated gasoline program as the modeled Clean Air Act programs) and Fig. 2-1 (demonstrating the NOx reductions associated with compliance with these programs).
[16] Alternative Fuels Data Center, Annual Vehicle Miles Traveled in the United States.

but exceed 1990 rates.[17] Air and truck miles have also increased. Transportation now represents 55 percent of the NOx and 29 percent of the CO_2 pollution in the U.S.—outpacing the power sector as the primary source of both pollutants.

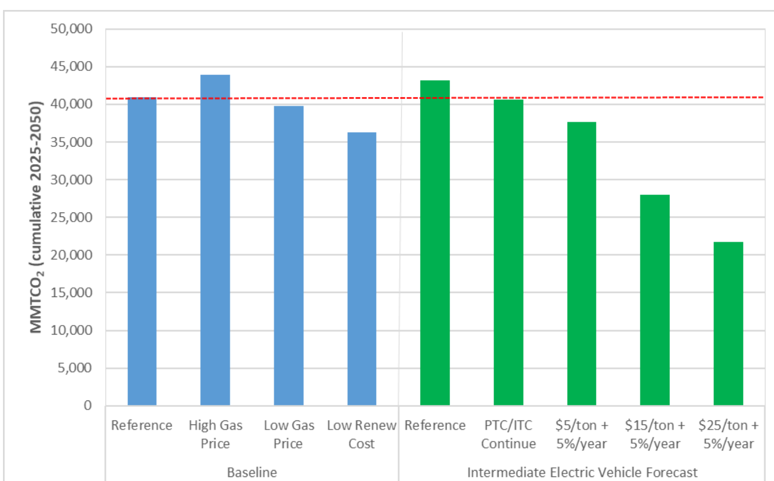
Given transportation's role as the largest contributor of NOx pollution, and as power generation becomes cleaner, states are looking to the transportation sector to improve air quality. In 22 states plus the District of Columbia, communities do not meet ozone air quality standards. Additional communities face periodic air quality alerts, when children, the elderly, and those with respiratory problems are warned to stay inside. In 22 of 35 metropolitan areas tracked by the EPA, the number of air quality alert days grew in 2018 over 2017. Electrification of personal vehicles, bus and car fleets, and trains can alleviate these local pollution problems.

Stabilizing and reducing power sector emissions while driving activity into this sector is complicated.[18] But through effective policy coordination, states can generate significant cobenefits, to maximize and fairly distribute the air quality benefits of electrifying motor vehicles.

A Nicholas Institute working paper demonstrates that increased electricity demand from electric vehicles should result in meaningful *net* NOx, SO_2, and CO_2 reductions. However, a combination of approaches will accentuate air quality benefits in both the power and transportation sectors, including policies that reduce emissions in the power sector, reduce nonelectrified transportation emissions, shift EV charging to low-demand hours or match demand to renewable generation, and monitor total air quality.

Figure 3 displays Nicholas Institute modeling results. The blue columns project power sector CO_2 emissions to 2050, absent vehicle electrification. Modeling shows emissions should remain steady or decline, although they could increase if high natural gas prices were to induce older coal units to remain online. The green columns present future power sector emissions with EV demand built in (19% VMT in 2030; 32% in 2050). Without companion policies (i.e., the reference case assumptions), new demand might increase power sector emissions. But the next four columns show that, for instance, the extension of federal renewable energy tax credits or modest carbon prices can reduce emissions even while the sector accommodates increased EV demand.

Figure 3. CO2 Emissions from Power Generation (2025–2050) Without/With EVs[19]



[17] Michael Sivak, Has Motorization in the U.S. Peaked? Part 10: Vehicle Ownership and Distance Driven, 1984 to 2016 (Jan. 2018). In 1990, per-person car ownership was 0.730 and per-household ownership, 1.953.
[18] Electric Power Research Institute, Advancing Efficient Electrification (Apr. 2018). The paper goes on to warn that "[f]or instance, monetary policies focused on PEV [personal electric vehicles] adoption separately could result in increased electricity associated emissions if not accompanied by appropriate emission standards."
[19] Credit: Martin Ross, Nicholas Institute for Environmental Policy Solutions, Duke University.

PART II: MODELING IMPLICATIONS OF ELECTRIC LIGHT-DUTY VEHICLES FOR ELECTRICITY GENERATION

EV demand influences power sector generation in two ways. First, it lifts the load curve by increasing the total kilowatt hours demanded from the grid. Second, it can reshape the load curve by potentially increasing peak demand, or filling in at low-demand times. It is important to model both effects, to predict which generation sources will be dispatched or ramped up to meet this new demand.

Nicholas Institute analyst Martin Ross used the electricity-dispatch model DIEM (Dynamic Integrated Economy/Energy/Emissions Model) to investigate the effects of personal electric vehicles (PEVs) on electricity generation and emissions of NOx, CO_2, and SO_2. Mirroring the description of the previous paragraph, the modeling set out to address two sets of questions:

- What types of electricity generation will meet new demand from different projections of PEV uptake, in the near-term (2035) and by 2050?
- Does this pattern change depending on relative costs of generation, the time of day vehicles are charged, and companion policies seeking to increase integration of renewables or internalize the cost of CO_2 pollution?

Dr. Ross modeled incremental electricity demand from electric vehicles at a national level and for a group of 18 east coast states and the District of Columbia, including all those situated along the Interstate 95 corridor.[20] This policy brief draws from the national analysis.

The analysis considered several PEV uptake scenarios from the National Renewable Energy Lab (NREL) and the U.S. Energy Information Administration (EIA). Ross also analyzed an Intermediate scenario where PEVs constitute 36 percent of vehicle miles traveled by 2050, a projection that falls half-way between the EIA projection (14 percent by 2050) and NREL's "medium" scenario (64 percent by 2050). The findings are summarized in the box on page 9.

Readers are encouraged to refer to the modeling paper for more detailed analysis. Several high-level points about the modeling results are worth making here:

- Across all PEV uptake and charging scenarios, meaningful net emissions reductions were realized across the transportation and power sectors. NOx emissions reductions from PEV displacement of internal combustion engines were 4 to 14 times larger than any increases in power plant emissions.
- A modest carbon price ($5/ton in 2025, + 5% each year; $17/ton in 2050) or extension of the federal Investment Tax Credit (ITC) and the Production Tax Credit (PTC) for renewable energy cut NOx and CO_2 emissions in the power *and* transportation sectors, for deeper reductions overall. (This was also true for SO_2 for all but one policy scenario—an ITC/PTC extension—when combined with NREL's MediumEV case.)
- Encouraging the charging of PEVs during the day, between the morning and evening peaks, can enable a growing share of solar generation to meet incremental PEV demand.

The working paper forms an analytical starting point for the policy exploration in the next section. Vehicle electrification alone can reduce emissions of NOx, CO_2, and SO_2 pollution across the power and transportation sectors. However, carbon regulation can ensure reductions in each sector and maximize total air quality benefits.

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[20] These were further broken down into Northeast States—Connecticut, Delaware, District of Columbia, Maine, Massachusetts, Maryland, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Virginia and Vermont; and Southeast States—Alabama, Florida, Georgia, North Carolina, South Carolina, and Tennessee.

Future modeling can and should be done for electrification of other types of vehicles, and other sectors including heavy industry and building heating. Moreover, examination of modeling results for other regions and additional modeling at a more granular level would assist in projecting and documenting community-level changes in air emissions resulting from electrification. This could inform State Implementation Plan submissions to U.S. EPA and environmental justice analyses, among other key applications.

PART III: COMPANION POLICIES TO ENHANCE AIR QUALITY BENEFITS OF VEHICLE ELECTRIFICATION

MODELING CONCLUSIONS

Emissions benefits of electric vehicles: Across all scenarios investigated, meaningful net reductions in NOx, CO_2, and SO_2 emissions occur.

Construction of new units. Reference assumptions from AEO 2019 project low natural gas prices; NGCC units could provide a significant share of new generation to meet EV demand.

Operation of existing units. EV demand also has the potential to keep existing nuclear and coal plants online, absent other policy interventions.

Generation by renewables. Over time, renewables play an increasing role in meeting EV demand, particularly solar PV. To achieve a significant shift into renewables and out of fossil generation may require additional policies.

NOx emissions benefits. Reductions in NOx from conventional light-duty vehicles significantly outweigh any increases in NOx emissions from electricity generation.

CO_2 emissions benefits. Net reductions in CO_2 emissions are always positive; emissions reductions from on-road vehicles are larger than any increases in generation emissions and increase over time as increase and renewables form a larger share of generation.

EV charging patterns. The timing of charging can have important impacts on generation choices. Cheap wind and solar enhance the benefits of EV charging when they tend to generate.

Role for Policy. Depending on market conditions, existing coal and new NGCC units could supply a nontrivial share of the electricity needed by EVs. Net emissions benefits can be increased significantly by pricing the carbon content of fossil fuels or subsidizing renewables.

Regulators and stakeholders have questions about the interplay of policies as transportation emissions are shifted to the power sector through electrification. How do sector-specific policies affect emissions across sectors? What behavioral and economic factors must be considered?

As observed in the modeling paper, some PEV uptake projections are starting to make a dent in overall demand on the power sector. And truck and bus charging (not considered here but critical) could represent a larger share of electricity demand, down the road. States and industry should consider a suite of strategies now, to ensure robust emissions reductions from electrification.

The remainder of the policy brief describes possible companion policies that could support and supplement the air quality goals of vehicle electrification policies. Companion policies may serve different purposes, from generating revenue to ensuring that power sector emissions do not backslide in the face of increased demand.

They also reflect different approaches: market- or incentive-based, technology-driven (or technology forcing), or command-and-control.

Table 1: Strategies of Policies to Maximize Air Quality Benefits of Vehicle Electrification

Policy	Revenue Generating	Provides Emissions Backstop	Info/ Process-Driven	Market-Based	Incentive-Based	Tech-Driven (or Tech-Forcing)	Unit-Specific/ Permit Limits
Declining Cap on Power Sector	Depends on design	x		Depends on design			Not likely, though could include facility-wide limits.
Promote Renewable Energy					x	x	
Consider CO2 in Utility Planning			x			x	
Low-Carbon Fuel Standard	Depends on design			x		x	x
ZEV Mandate						x	
Declining Cap on Transportation Sector	Depends on design	x		Depends on design			Depends on design
Efficiency/ Emissions Standards for Vehicles						x	x
Time-of-Use Pricing for EV Charging				x	x		
Charging Apps			x	x		x	
Adapt Demand Charges					x		
Promote Storage					x	x	
Track Community Emissions			x				
Mapping			x				

Some policies might be more beneficial when implemented in parallel, or serially, to maximize air quality and equity benefits. The list is not meant to be prescriptive or exhaustive, but to stimulate discussion and catalyze cross-sector policymaking.

Power Sector Decarbonization Policies

Set a Declining Carbon Cap on the Power Sector

In the Nicholas Institute modeling, a modest price on power sector carbon enhanced CO_2 reduction benefits from transportation electrification (Fig. 4). Notably, that carbon price also drove deeper NOx emission reductions (Fig. 5).

Carbon pricing could take the form of a CO_2 tax, or a declining cap on the power sector that sells carbon allowances to emitters or enables the sale or purchase of allowances between sources. Of the two forms, carbon caps have proven more popular in the United States, in part because a cap guarantees an environmental outcome. Moreover, because the mechanism has been used to limit pollution for decades in federal and state air pollution regulation of the power sector, it has become a familiar policy tool for regulators and industry.

Figure 4. Net Changes in CO2 Emissions from Generation and EVs (2025–2050)[21]

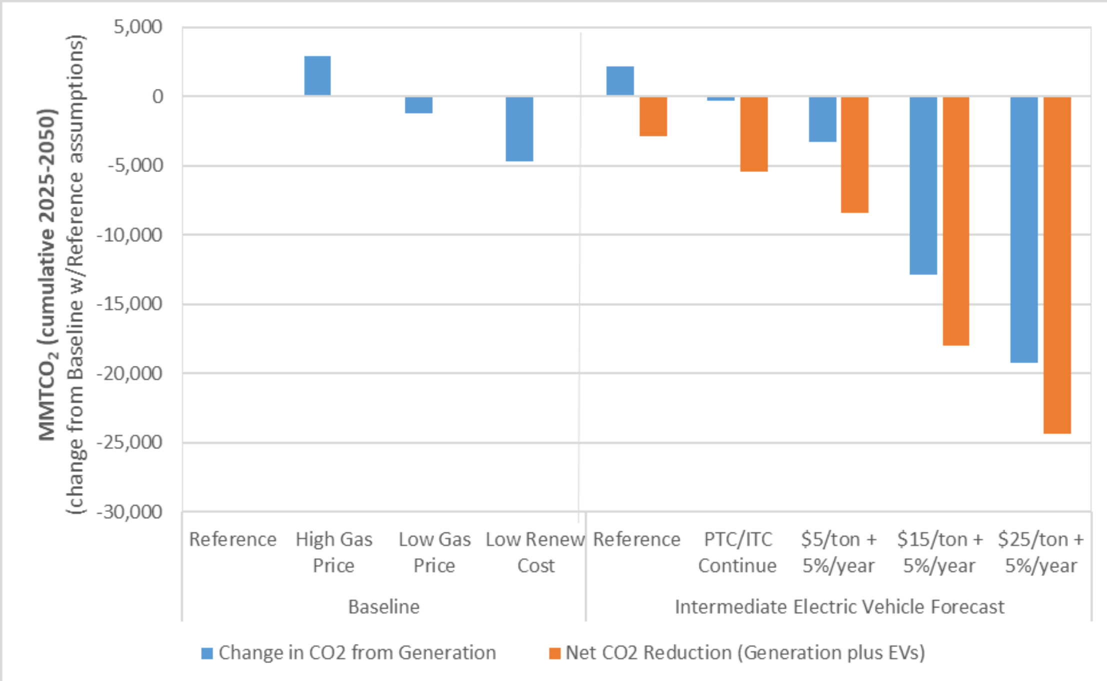
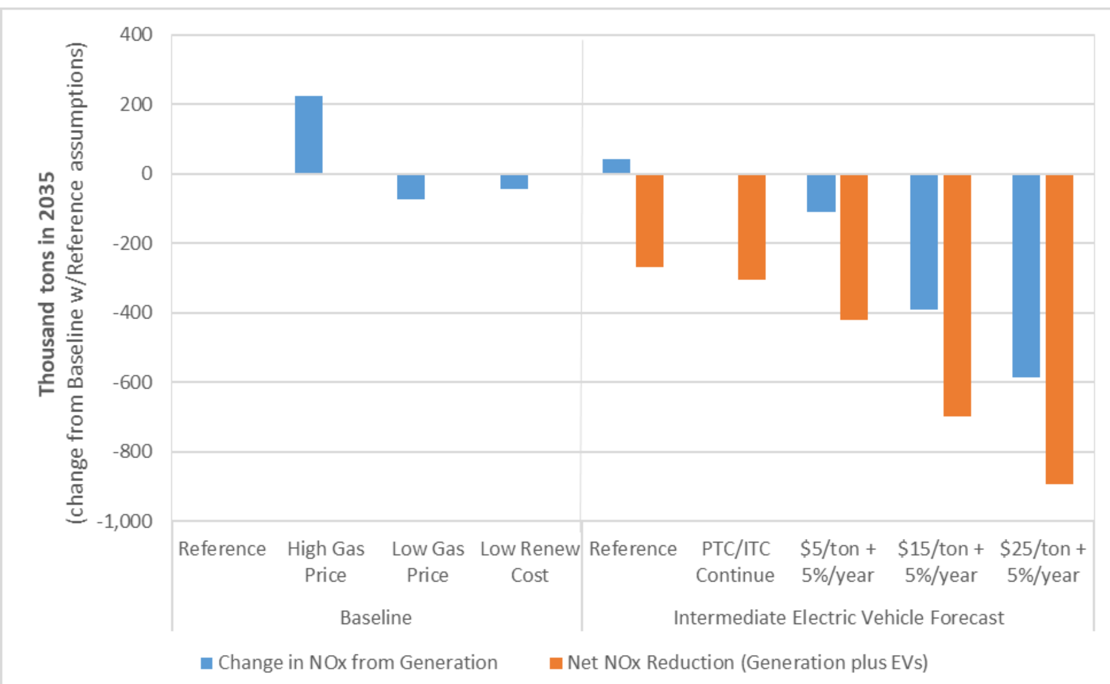


Figure 5. Net Changes in NOx Emissions from Generation and EVs (2035)[22]



The Regional Greenhouse Gas Initiative (RGGI) is America's first mandatory market-based effort to reduce CO2 emissions. It is a cooperative effort among nine states—Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont—to cap and reduce pollution from the power sector. In 2019, Pennsylvania announced its intention to join RGGI and Virginia finalized a rule to cap CO2 emissions

[21] Credit: Martin Ross, Nicholas Institute for Environmental Policy Solutions, Duke University.
[22] Credit: Martin Ross, Nicholas Institute for Environmental Policy Solutions, Duke University.

from its power sector. New Jersey is poised to rejoin RGGI in 2020. California, meanwhile, has implemented an economy-wide cap on carbon pollution.

A carbon cap that requires emitters to purchase shares of pollution can also generate revenue to increase EV uptake or reduce CO_2 emissions in the power sector. For instance, Delaware directed some of the revenues from its participation in RGGI to fund EV charging infrastructure.[23] Several states have invested auction proceeds into energy efficiency.

Promote Renewable Energy

A price or cap on carbon can discourage the use of more carbon-intensive generation, but other policies may do more to drive generation from zero-carbon resources. For instance, since 1992, the federal government has offered a Production Tax Credit for new wind projects. Despite the periodic uncertainty around the continuation of this tax credit, the American Wind Energy Association credits the tax credit with wind installation becoming 69% more affordable since 2008. In 2005, Congress added an Investment Tax Credit for solar projects; since that time the solar industry has grown more than 10,000 percent. Both federal tax credits have begun to wind down as of 2019, though there is a push to extend them. The modeling analysis suggests that continuation of these credits could potentially allow all EV charging to be supplied by renewables.

Meanwhile, some states have directed the procurement of renewable energy through processes run by the state, as in Connecticut, or by one or more utilities, as in North Carolina. These policies help to get renewable energy projects built. However, if these sources generate more electricity than the system needs, they may be curtailed.

Other types of policies require that a certain share of a utility's load is met by generation from renewable energy production. As noted above, 29 states plus the District of Columbia have Renewable Portfolio Standards (RPS), covering 63 percent of U.S. electricity retail sales. Many RPS increase the share of load to be met by renewable energy, up to a certain date, and then level out. In recent years, states have begun to extend and increase their standards.

State RPS most often support wind and solar, but may also include other resources, including geothermal, swine and poultry waste, biomass, and waste coal. As electrification increases electricity demand, it will become more important to establish whether these energy sources reduce air emissions across their life cycle. Such calculations may require reaching beyond the power and transportation sectors to account for emissions in the agricultural and mining sectors.

In addition, some states have carved out a share of an RPS for particular resources, from solar and offshore wind in Maryland to distributed generation resources like rooftop solar in Colorado. Alternatively, states may award bonus credits or apply credit "multipliers" to projects that meet particular policy goals. For instance, Nevada has offered 2.45 credits for every kilowatt hour of electricity produced with behind the meter solar,[24] and 2 credits for energy efficiency projects that reduce peak time use.[25] Washington State contemplated offering a 2.5 RPS credit multiplier for renewable energy backed up by energy storage, but did not enact this proposal.

Other states have created programs to encourage projects with particular attributes; for instance, the NY-Sun program gives enhanced incentives to solar projects sited on brownfields.[26]

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[23] Ten percent of Delaware's RGGI proceeds go to Greenhouse Gas Reduction Projects. Del. Nat. Res. Code § 6046(c)(4). The RGGI Proceeds Report for 2016 indicated that the Secretary of the Department of Natural Resources and Environmental Control awarded these funds to state Department of Transportation rebates for EVs and charging infrastructure. The Investment of RGGI Proceeds in 2016 (Sept. 2018) (last visited July 17, 2019).
[24] Nevada Revised Stat. § 704.7822.
[25] Nevada Revised Stat. § 704.78215(2) (authorizing bonus credits for peak time energy efficiency); Nevada Admin. Code § 704.8927(7).
[26] U.S. EPA, RE-Powering America's Land Initiative: Tracking Completed Projects on Contaminated Lands, Landfills, and Mine Sites (January 2019) (last visited July 16, 2019), at 5.

Incentivizing the installation of renewable energy, and establishing, extending, or increasing a state RPS could complement an electrification agenda. The Ross paper analyzed the effect of extending the federal renewable energy tax credits, or lower renewable energy costs more generally (either due to policy or market forces or both). Figures 3 and 4 demonstrate the modelled outcomes of each of these scenarios.

At a workshop held at Duke University in April 2019, experts discussed how states might create or amend an RPS to offer a carveout or credit multiplier to projects that marry up renewable energy production and EV charging demand. This would minimize curtailment of renewables. For instance, a company might propose the installation of solar at its facility and then offer a workplace EV charging program for the corporate fleet or employees who own EVs. Such an arrangement would be analogous to solar-and-storage projects that "firm up" the otherwise intermittent generation resource and allow it to be dispatched as needed to meet demand. (Encouraging EV charging during times when renewable energy is generated could likewise capture the most benefit, see the time-of-use pricing section below.)

Companion policies that encourage storage technologies also could enable higher penetration of renewables to meet new demand from electrification. Alternatively, the electrified technologies themselves—from a residential hot water heater to an electric truck—might provide energy storage services to the grid. The federal Investment Tax Credit may be used for battery systems charged by renewable energy; states might consider similar types of incentives. A longer description of battery storage may be found below, in the "Load Management" section.

A state need not choose between a price on carbon and support of renewable energy technologies; a number of states have pursued both. According to a 2019 paper by Resources for the Future, deploying both policies can maximize decarbonization and ensure that the incremental increases in demand posed by electrification are more likely to be met with lower-emitting and nonemitting electric generation resources.

Integrate Carbon Pollution Considerations into Utility Planning

States that direct utilities to submit Integrated Resource Plans (IRPs) could require these plans to account for the CO2 or other emissions that result from different planning scenarios and to make decisions based on air quality information.[27] A typical IRP includes an electric utility's demand projections, as well as plans for upgrading, replacing, or supplementing existing infrastructure to meet that future demand. But Minnesota also accounts for pollution impacts of utility decisions through an administratively determined Social Cost of Carbon. And in 2019, the North Carolina Utilities Commission directed Duke Energy to demonstrate in IRP modeling how the utility plans to meet Governor Cooper's 2025 greenhouse gas targets. Accounting for air pollution impacts in an IRP creates a public record that could stimulate a constructive dialogue between utilities and regulators about how to mitigate those impacts. It might also provide a building block for new decision-making tools at the Public Utilities Commission.

Companion Transportation Sector Decarbonization Policies

States also might consider nonelectrification policies that drive reductions in the transportation sector. These policies could generate revenue streams to fund EV charging and transit infrastructure. They might also reduce pollution and vehicle miles traveled among all transportation vehicles, including those with internal combustion engines.

While outside the scope of this policy brief, transportation infrastructure funding is a critical part of any electrification and decarbonization policy. State and federal highway funds are largely paid for through fuel taxes. If and as transportation vehicle fuel consumption decreases, alternative sources of funding may be needed.

[27] According to Advanced Energy, 33 states require pollution information from investor-owned utilities. Most do not require resource decision-making to be influenced by this information.

A number of alternative funding mechanisms have been proposed or implemented, from increasing fuel taxes, imposing highway use fees on EVs and heavy-duty trucks,[28] to building toll roads and charging vehicle owners based on vehicle miles traveled. New funding sources should be evaluated to ensure they do not discourage vehicle electrification or impose a regressive tax on low-income households.

Establish a Low Carbon Fuel Standard

California implemented a Low Carbon Fuel Standard (LCFS) in 2009.[29] The standard is actually a set of declining carbon intensity standards or benchmarks for different types of transportation fuels, based on their life cycle emissions. Fuel suppliers must meet those benchmarks on average across their fuel supplies. If a fuel has higher carbon intensity than the benchmark for its type, the supplier must purchase credits; if a fuel has lower carbon intensity than the relevant benchmark, its supplier may generate credits for the market.[30] Credits could be generated by EVs, but only if their charging stations were collocated with renewable energy generation.[31] Of the five million credits sold or traded in 2016, nine percent were generated by electric vehicle charging.[32]

In updates to the LCFS,[33] California made changes to further incentivize deployment of EVs. First, EV charging would be eligible to generate LCFS credits so long as renewable energy was generated in the same balancing authority (rather than physically collocated with the charging infrastructure). Second, EV charging would receive bonus credits if done during a time when excess renewable energy is being produced.[34] These changes should fund additional EV charging infrastructure, paid for by higher-emitting transportation fuels.

Oregon also has an LCFS.[35] States with domestic sources of biofuels or other fuels currently trying to sell into California's market might be particularly well positioned to explore this policy option. An LCFS not only complements EV policies by reducing transportation emissions across the board but can reinforce EV policies by creating a revenue stream for charging infrastructure and shifting charging to times when the grid is cleaner.

Set a Declining Cap on Transportation Emissions

Alongside a cap on CO2 emissions from the power sector, states may cap emissions from the transportation sector as well. A cap would serve as a backstop, ensuring the stabilization and then decline of emissions from this sector. A state might combine a cap for the power and transportation sectors or enable more limited trading between separate programs, to guarantee net emissions reductions across both sectors. Or, a state could cap transportation as part of an economy-wide cap on CO2; for instance, California's cap covers upstream fuel distributors.

Since 1990, U.S. power sector emissions have held steady while producing 30 percent more electricity, while the country's transportation emissions have grown 21 percent.[36] Given this, experts at the April Duke University workshop raised concerns that a combined cap might disincentivize action in the transportation sector so long as power sector reductions were more readily available. However, a combined cap in tandem with an aggressive vehicle electrification policy might alleviate these concerns. Moreover, experts suggested that if a state were to

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[28] D. Farnsworth, J. Shipley, J. Sliger, and J. Lazar, Beneficial Electrification of Transportation, Regulatory Assistance Project (Jan. 2019), at 73–78.

[29] Cal. Health & Safety Code § 38561. The idea was proposed in a scoping plan directed by AB32, the California Global Warming Solutions Act of 2006

[30] 17 Cal. Code of Reg. §§ 95480-95503 (2010); see also California Air Resources Board, What is LCFS?.

[31] California Air Resources Board, Public Hearing to Consider Proposed Amendments to the Low Carbon Fuel Standard Regulation and to the Regulation on Commercialization of Alternative Diesel Fuels, Staff Report: Initial Statement of Reasons (Mar. 6, 2018), at EX-2.

[32] Id. Most of the credits—about 82%—were generated by lower-carbon ethanol and renewable diesel or biodiesel.

[33] 17 Cal. Code of Reg. §§ 95480-95503 (2018).

[34] California Air Resources Board, Staff Report: Initial Statement of Reasons (Mar. 6, 2018), at EX-4-5, II-10; see also, Debra Kahn, California to Extend Low-Carbon Fuel Standard Through 2030, Scientific American (Apr. 30, 2018). For more on shifting EV load to match renewable generation, see p. x of this policy brief.

[35] See Oregon H.B. 2186 (2009); Oregon Dep't of Environmental Quality, Chapter 340, Division 253, Oregon Clean Fuels Program (2019).

[36] D. Farnsworth et al., supra n. 18, at 44 (citing U.S. EIA and U.S. EPA statistics).

require emitters to purchase pollution allowances, combining the caps now or in the future would streamline revenue allocations for further emission reductions work. The multistate Transportation Climate Initiative (TCI) is exploring these types of policies and is worth watching closely in 2019–2020.

Support Stronger Fuel Efficiency Standards

In 1975 and 2007, Congress set and raised fuel efficiency standards for passenger vehicles sold in the United States.[37] In 2009 and 2012, the U.S. EPA and the National Highway Traffic Safety Administration (NHTSA) issued joint rules to set fuel efficiency and CO2 emissions standards for cars and light trucks. California is authorized under the Clean Air Act to set its own fuel efficiency standards[38] but agreed to join this deal to support the first-ever federal GHG car standards. The 2012 light duty vehicle standards, covering model years 2017–2025, were projected to raise average fuel economy in 2025 to between 48.7 and 49.7 miles per gallon, and reduce American oil consumption three million barrels a day by 2035. Standards were also set for heavy-duty vehicles. The Trump administration has proposed to weaken both standards. In addition, NHTSA has delayed a penalty increase for noncompliant auto manufacturers.

States have incorporated these fuel efficiency standards into air quality projections and program planning. As a result, some states are opposing the loosening of federal standards. In addition, California is fighting to keep its special authority under the Act, in part to maintain tougher standards if the EPA were to proceed with the federal roll-back. (Once in place, the Act treats California standards as on par with federal standards, enabling other states to follow California standards in lieu of those issued by the EPA.[39]) The EPA announced in September 2019 that it would in fact revoke Californias so-called waiver authority. But in November 2019, it appeared the EPA might back off plans to lower the fuel efficiency and CO_2 emissions standards for FY21 to FY25, amid reports that the agency could not demonstrate economic benefits to the rollback.

Adopt a Zero Emission Vehicle (ZEV) Mandate

For states reluctant to pick one "winner" from among the potential nonemitting vehicle technologies, a Zero Emission Vehicle mandate or target might be an appealing policy tool. California's ZEV mandate requires automakers to sell a certain percentage of nonemitting vehicles each year based on their total sales. This mandate, which nine states have adopted,[40] will require about 8 percent of vehicles sales in 2025 to be nonemitting vehicles. This might include EVs, plug-in hybrids, hydrogen fuel cell cars, or some other new technology.

Load Management Policies

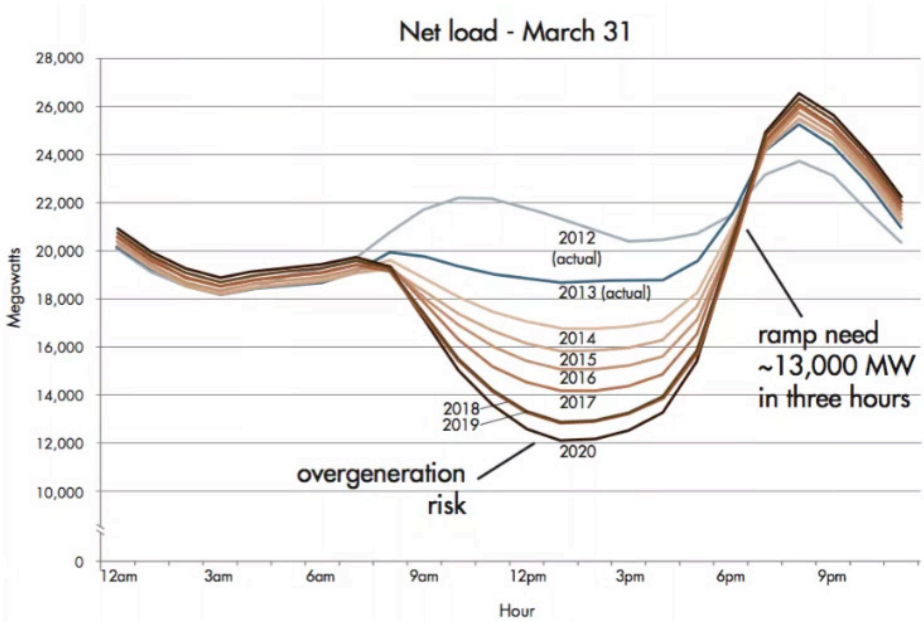
PEVs are considered "flexible loads" because they do not require electricity at fixed times. Policies that encourage PEV charging during times of otherwise low electricity demand, then, can even out demand over the course of a day, avoiding expensive peak power purchases on the spot market. Alternatively, policies might encourage PEV charging when excess renewable energy is available and at risk of curtailment without sufficient demand.

The modeling analysis suggested that the time of charging affects the types of generation called on to meet incremental increased demand, and could have a significant impact on peak demand, with implications for future capacity needs. Careful management of PEV charging could help mitigate the "duck curve" problem

[37] Energy Policy and Conservation Act of 1975, Pub. L. 94-163, 89 Stat. 871; Energy Independence and Security Act of 2007, Pub. L. 110-140, 121 Stat. 1492.
[38] 42 U.S.C. §7543(b).
[39] 42 U.S.C. §7543(b)(3).
[40] These states are Connecticut, Maine, Maryland, Massachusetts, New Jersey, New York, Oregon, Rhode Island, and Vermont. In September 2019, Minnesota and New Mexico announced their intention to adopt the mandate, too.

(Fig. 6), promote grid reliability by providing frequency regulation and voltage support services,[41] and increase the capacity factors of renewable generating resources.

Figure 6. Depiction of the "Duck Curve" Based on Solar in California ISO Territory



CAISO

Promote Time-of-Use Pricing for Residential Charging

The modeling paper looked at four charging time patterns: "Home" charging which occurred mostly in the late afternoon and early evening; "Home and Public" charging that featured two peaks, mid-morning and evening; "(mostly) Night" which had some mid-day charging but most charging done at night; and "(mostly) Day" which emphasized midday charging. The results suggest that these charging patterns resulted in different generation being called on to meet the incremental EV demand, particularly by 2050. For instance, "(mostly) Day" led to the highest solar share of EV demand; "Home" called on a more modest about of solar; "Home and Public" and "(mostly) Night" tended to drive more gas into the mix since many cost-effective wind sites would be developed regardless of demand from vehicles.

Today, up to 80 percent of PEV charging occurs at home.[42] Some charging behavior studies indicate that without external signals, many PEV owners may charge as soon as they arrive to work, but most will charge in the evenings at home or at public charging locations.[43] This results in most PEVs being charged from the late afternoon to early evening, which coincides with other peak demand periods. As most utilities do not price electricity based on when it is used, PEV owners do not see the increased costs when a utility has to purchase additional peak power on the spot market, or plan to purchase or build increased generation capacity to meet that new, higher peak. But ultimately, these higher costs are passed on to all electricity consumers.

Time-of-use (TOU) electricity pricing could send a signal to charge when demand is slack, or when excess renewable generation is available. TOU pricing defines different prices for units of electricity, as a function of the time of the day when the electricity is consumed. Prices increase during peak demand and reduce during

[41] See, e.g., D. Farnsworth et al., supra n. 18, at 41.
[42] Brian Jones, Grace Vermeer, Kim Voellmann, Paul Allen, Accelerating the Electric Vehicle Market: Potential Roles of Electric Utilities in the Northeast and Mid-Atlantic States, MJ Bradley & Associates (March 2017), at 6 (citing a study of 4 million charging events, see U.S. Dep't of Energy, The EV Project (last visited July 19, 2019)).
[43] S. Hardman, A. Jenn, G. Tal, J. Axsen, G. Beard et al., A Review of Consumer Preferences of and Interactions with Electric Vehicle Charging Infrastructure, Transp. Research Part D 62, 508–523 (2018), at 517.

hours of low demand, reflecting the true cost of electricity generation and supply. This encourages consumers to shift their charging hours to off-peak periods. TOU pricing can play a crucial role for utilities that are trying to manage the additional load that electric vehicles (EVs) bring to the grid.

In the United States as of May 2019, 33 utilities in 22 states have defined and established residential TOU pricing for residential EV charging. Still more utilities are running pilot programs. A brief description of each of these utility programs is available online. The TOU rate designs are similar; most utilities define rates for two time periods, on-peak and off-peak. However, some define a third time period, mid-peak (daytime hours) or super off-peak (early morning or late-night hours, with lowest rates). Each of these periods are defined for summer and winter/non-summer months. Seasons and time periods vary in definition across the country, depending on the local weather conditions. On-peak rates can be as high as 56.7 cents per kilowatt hour consumed and off-peak rates can be as low as 1.4 cents per kilowatt-hour consumed (depending on the state) to induce load shifting.

TOU rates might apply to an entire home, or just to the home's EV charging outlet. In addition, MJ Bradley & Associates have suggested using utility cash incentive programs, to reward customers who charge their PEVs during low demand times or submit to controlled charging—whereby the utility can determine when power flows through the customer's EV charging ports.[44] In turn, the utility might be able to aggregate homes with controlled charging into a demand response bid in a wholesale electricity or capacity market. These rate structures and incentives might also work to optimize charging when excess renewable energy is available. Going forward, utilities might consider setting more time-of-use pricing options across shorter intervals, to drive charging (and other demand) to optimal times.

Deploy Technology to Manage Charging Times

EVs are readily adaptable as grid management tools because they already contain digital controls that could be used for communicating with the grid.[45] However, smart meters and outlets are also needed to facilitate TOU pricing and controlled charging. Just over half of electricity customers in the United States have a smart meter, as of 2017;[46] the U.S. Energy Information Administration credits state policies for the deployment of smart meters. Meanwhile, the Regulatory Assistance Project has encouraged national standards for new EV charging outlets, to require that they contain Wi-Fi capability to facilitate grid integration.[47]

In addition, phone and web applications enable a PEV owner to track their PEV charging times and costs to make informed decisions about when to charge.[48] Future applications might help a consumer opt-in to a demand response bid on the spot market during a peak demand period, or charge upon receiving alerts that renewable generation in the area may be curtailed. (Busy consumers might be willing to share cost savings with a third party to manage this for them.)

Innovative technology could be combined with new algorithms[49] and business models to enhance demand response and grid management capabilities of a utility or demand response aggregator. State and corporate

[44] B. Jones et al., supra n. 30, at 17. A load controller can be installed between the load and the grid, "which monitors the battery condition and enables/disables the charging process via a switch." X. Geng and P.P. Khargonekar, Electric Vehicles as Flexible Loads: Algorithms to Optimate Aggregate Behavior, 2012 IEEE Third International Conference on Smart Grid Communications (5–8 Nov. 2012).
[45] D. Farnsworth et al., supra n. 18, at 37 (citing A. Langton and N. Crisostomo, Vehicle-Grid Integration: A Vision for Zero-Emission Transportation Interconnected Throughout California's Electricity System, California Public Utilities Commission (Oct. 2013)).
[46] U.S. EIA, Nearly Half of all U.S. Electricity Customers Have Smart Meters (Dec. 6, 2017) (using data through 2016); U.S. EIA, How Many Smart Meters are Installed in the United States, and Who Has Them? (Oct. 26, 2018) (updating data through 2017).
[47] D. Farnsworth et al., supra n. 18, at 59–60.
[48] See, e.g., VersiCharge Smartgrid by Siemens (enabling users to monitor charging status, set charging schedules, and track energy usage), the Sense app (offering similar features); see also Wattsly and the Tesla app.
[49] See, e.g., X. Geng and P.P. Khargonekar, supra n. 32.

research investments, and support for research incubators like GreenTown Labs and the Joules Accelerator, can stimulate this innovation.

Adapt Demand Charges to Support Commercial, Industrial, and Public Charging

While most PEV charging happens at home, charging stations at work, shopping malls, destination spots, and along the highway are critical. They offer more options to the PEV owner, reduce range anxiety, and increase general consumer confidence in these vehicles. In addition, workplace EV charging infrastructure enable cars to charge on slower charging infrastructure[50] at optimal times during the day, for instance outside of peak demand hours and when PV solar is generating the most electricity. TOU pricing is already relatively common among commercial and industrial customers and may be adapted to encourage or direct optimal charging.

On the other hand, demand charges for commercial, industrial, and municipal customers might have to be adapted so as not to discourage PEV charging. Demand charges are fixed charges calculated based on the peak use for that customer in the previous month.[51] The charge is intended to reflect additional costs the utility may have to incur to guarantee delivery of that "high point" in consumption at any given point in time.

Some large customers balk at demand charges for what are known as "non-coincident peak loads"—when the maximum load in a month for a customer does not match up to the system's peak load. In addition, several recent reports suggest that demand charges might incidentally discourage commercial and industrial sites from offering PEV charging for fear that charging by multiple employees at once might create a new peak load and therefore higher demand charges.[52] A similar concern was raised at a 2018 Environmental Policy Council meeting in Raleigh, North Carolina, about the suppressive effect of demand charges on rural PEV charging stations.[53] As more PEVs come online, demand charges might need to be reshaped, to balance the utility's need to make infrastructure investments and a customer's incentive to offer EV charging.

A 2017 report found that 63 of the Fortune 100 companies and nearly half of the Fortune 500 companies have at least one clean energy target. Many of these companies—from Starbucks and Ikea to Walmart and UPS—are located in communities across the United States and interface with hundreds of thousands of employees, customers, and neighbors each year. States and utilities might consider partnering with such companies to pilot EV charging initiatives. These initiatives might experiment with new demand charges and EV charging rate structures, and track EV uptake and charging infrastructure use among employees and customers. More ambitious programs might test corporate fleets for use as vehicle-to-grid services, or incentivize corporate support of electrified bus fleets in surrounding communities.

Incentivize Storage

Another way to smooth out supply and demand curves while enabling increased generation from zero-emitting renewables while maintaining grid reliability is to "firm up" renewable-generated electricity with storage. For instance, as illustrated in Figure 6, excess solar power generated between noon and 3 p.m., when daily demand is relatively low. Pumped hydro or batteries could store some of that excess power for use in the late afternoon, when demand increases precipitously just as the sun is lowering in the sky and solar production drops off.

Costs for solar-and-storage systems remain relatively high. According to asset management firm Lazard's Levelized Cost of Electricity Analysis for 2018, solar thermal towers plus storage cost between $98–181/MWh;

[50] Slower-charging outlets are lower voltage and therefore less demanding on the grid. However, they are more appropriate at sites where vehicles are likely to sit idle for a relatively long time, such as workplaces or homes.
[51] For further discussion on demand charges, see Gwendolyn Brown, Making Sense of Demand Charges: What are They and How do They Work?, Renewable Energy World (June 6, 2017).
[52] See, e.g., B. Jones et al., supra n. 30, at 18–19; D. Farnsworth et al., supra n. 18, at 67–68.
[53] Marcy Bauer, EVGO, EV Outlook and Projections from the Private Sector, Presentation at the North Carolina Energy Policy Council Meeting, Feb. 21, 2018.

by comparison, new natural gas combined cycle plants cost between $41–74/MWh. However, lithium ion battery costs have been dropping precipitously; one industry study found that battery prices had dropped 35 percent just in 2018 and 76 percent since 2012. A 2018 NREL study noted that developers can bring costs down further, for instance by collocating PV and storage systems, and using direct current coupling.

States might consider installed storage capacity targets, or carveouts and multipliers in Renewable Portfolio Standards. In addition, states with utilities participating in competitive wholesale electricity markets could advocate for storage-friendly market rules. In 2018, the Federal Energy Regulatory Commission directed markets to review their rules for barriers to participation by electric storage resources, creating a venue for these discussions. Finally, competitive electricity markets and state utility commissions could account for the grid services that storage can provide, such as frequency regulation and transmission or distribution capacity deferral, generating new revenue streams and shortening the payback time on financing.

In some cases, PEVs and other electrified technologies could provide energy storage services as well. National labs and other research institutions have studied "vehicle-to-grid" projects that use PEV batteries as grid storage, although current car battery warranties prohibit this kind of use.

A recent study estimated that PEV demand response could deliver the same benefits as California's storage mandate in firming up renewables, at much lower cost.[54] Therefore, thinking about "storage" as a broader concept than battery deployment is important. A combination of storage and demand response/management tools may be the most cost-effective approach to achieve a range of policy goals, including pollution reduction, lowered costs, equity, grid stability and reliability, grid automation, and flexibility.

Data Gathering Policies, for Air Quality and Equity Outcomes

Nicholas Institute modeling demonstrated that EV uptake should result in meaningful net emissions reductions across the power and transportation sectors. However, some studies have suggested that the costs and benefits of electrification are not distributed equitably.

One paper estimated regional and local emissions shifts based on the number and location of EVs registered in the United States by June 2014. The researchers found that the electricity generation mix of each region mattered. In the West, "the environmental benefits are positive and substantial," while at the time, in a more coal-intensive South, the emissions reductions realized by electrification were offset by greater pollution increases from the electric fleet. This is changing rapidly; subsequent research by the same team found that by 2017, due to substantial drops in power sector emissions, EV uptake yields net air pollution benefits in all U.S. regions.[55] Still, the research team argued that air quality impacts should be monitored at a still more granular level to ensure that all communities benefit from improvements in local air quality.

As the 2019 research suggests, EV uptake is increasingly becoming a reliable method for realizing net emissions reductions between the power and transportation sectors. However, it is vital to collect data at the national, regional, and community level to confirm the benefits and guide policies to address locations that are carrying increased or sustained pollution burdens as a result of vehicle electrification.

[54] D. Farnsworth et al., supra n. 18, at 41 (citing J. Coignard, S. Saxena, J. Greenblatt, and D. Wang, Clean Vehicles as an Enabler for a Clean Electricity Grid. Environmental Research Letters, 13(5) (May 16, 2018)).

[55] S.P. Holland, E.T. Mansur, N.Z. Muller, and A.J. Yates, Decompositions and Policy Consequences of an Extraordinary Decline in Air Pollution from Electricity Generation (June 20, 2019) (on file with author). Still, the paper posits that the federal EV tax credit is too large given the monetized air quality benefits realized by each car.

Collect Data to Track and Reduce Community-Level Emissions

In some cases, data are available but not used for decision-making by utility commissions or air quality offices. Air quality monitors exist in many communities but may not be tracked for trends that could be correlated against vehicle electrification. Some existing data could be reported in more helpful ways; for instance, state EV registrations could distinguish between on-road vehicles and off-road vehicles such as golf carts.

States could create air quality projections based on modeling and from IRPs, if utilities are directed to report the anticipated emissions outcomes of their policies. States could then implement air quality monitoring programs, with sensors placed in more heavily polluted communities, to ensure programs are achieving emissions reductions. As part of the legislative deal to extend authorization for its economy-wide carbon cap-and-trade program, California also enacted AB 617, to monitor communities for toxic and criteria air pollution. The law also expedites pollution controls for emission sources located in communities with poor air quality. Similarly, New York's 2019 climate legislation calls for a strategy to reduce toxic and criteria air pollutants in disadvantaged communities, followed by action plans.

States could compile additional air quality monitoring data from citizen scientists collecting data in their communities. Meanwhile, non-air data are also important to collect and make accessible; for instance, Purdue researchers reported that it was difficult or impossible to find reliable data on average annual mileage per vehicle and per person, the age of the vehicle fleet in Indiana, and local road traffic counts, when evaluating and building models to predict VMT.[56] Time and cost considerations grow as analyses seek to go more granular (e.g., to the county and census tract levels), suggesting a need for more robust estimation methods.

States that have set PEV uptake targets should identify the metrics to track to ensure that electrification delivers the highest net air quality benefits to the greatest number of communities.

Invest in "Actionable Mapping"

Spatial analysis in particularly important in assessing the distributional impacts of electrifying part of the personal vehicle fleet. Therefore, maps should be created and shared among policymakers and the public, to inform decision-making.

For instance, a state looking to improve air quality in an urban area might consider including a vehicle electrification initiative as a voluntary mobile source emission reduction program in a State Implementation Plan. Maps that establish where PEVs have been purchased and the miles they are likely to travel within that air quality management area would be useful in making the case to the EPA for inclusion of this program.

Maps could also be used to identify which communities are benefitting from current and future planned electrification efforts, and which are facing net air quality harms from the policy. Maps can sometimes be generated with community involvement, to facilitate trust in the outcome. Where electrification has been net positive, policymakers can stay the course or scale up a pilot project. Where electrification has not delivered benefits, these maps can enable constructive engagement on the amount of harm that may be attributable to electrification and the appropriate mitigation responses, including adapting existing electrification policies, enhancing investments in other pollution-reduction activities, or compensating communities in some other way.

Map can suggest where charging infrastructure should be located, as well. In counties or census tracts with a high rate of multifamily housing, residential EV charging is less likely to be available. Public charging stations in those areas are more likely to induce local EV uptake than public stations located in a heavily residential community made up of single-family homes.

[56] T.J. Klatko, B.R. Agbelie, S. Labi, J.D. Fricker, and K.C. Sinha, Estimation and Prediction of State Vehicle Miles Traveled (VMT) by Highway Category and Vehicle Classification, Joint Transportation Research Program, THWA/IN/JTRP-2016/04 (2016), at Table 3.1, 36.

Even at lower PEV uptake rates, a "cluster" of vehicles charging in one neighborhood could stress the distribution system.[57] Mapping can help to identify optimal charging locations based on where the distribution system has underutilized capacity. Several California utilities have published Interconnection Capacity maps, to show where interconnection of renewables would be easiest and lowest cost. This type of mapping has the potential to inform project siting where there is existing grid capacity and speed up the interconnection process. Similar maps could be used to encourage smart siting of EV charging stations.

CONCLUSION

Vehicle electrification holds great promise in reducing NOx, CO_2, and SO_2 emissions across the power and transportation sectors. But to maximize these reductions and ensure air quality improvements for all communities, companion policies may be necessary. These policies might generate revenue for EV infrastructure or air pollution mitigation programs in overburdened neighborhoods. They might set an emissions backstop, drive innovation, or produce important data. They might be proscriptive, or merely offer incentives to an industry or individual. There are plenty of tools in the toolbox to meet different circumstances or policy philosophies. It is worth considering the range of possibilities, and implementing a comprehensive air quality strategy, in advance of rapid electrification of our transportation sector.

[57] B. Jones et al., supra n. 30, at 9.

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Nicholas Institute for Environmental Policy Solutions

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