

# Comment for TCI's Regional Policy Design Process: Interactions of Transportation Carbon Pricing with the Electricity Market

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February 28, 2020

Twelve northeast and mid-Atlantic states and the District of Columbia are participating in the [Transportation Climate Initiative \(TCI\)](#), a regional transportation effort to coordinate investment in cleaner transportation and infrastructure.<sup>2</sup> One expected element of the program is a price on carbon emissions from transportation, which could yield billions of dollars for investment.

This comment examines how the introduction of a carbon price through a cap-and-trade program in the transportation sector might affect the electricity sector. One way it might affect the electricity sector is if TCI accelerates the adoption of electric vehicles. The demand for electricity to charge those vehicles could affect decisions about investment and operation in the electricity sector, its environmental outcomes, and prices. Further, the electricity sector in this region is already subject to carbon pricing through the [Regional Greenhouse Gas Initiative \(RGGI\)](#) cap-and-trade program.<sup>3</sup> Consequently, a second way TCI could affect the electricity sector is if it led to an increase in the demand for emissions allowances in the RGGI market, which would push up the RGGI allowance price.

Our conclusions are:

- **A carbon price in TCI can be expected to have nearly unobservable effects on the electricity sector.** The change in demand for electricity for personal transportation due to a carbon price in TCI will remain a small portion of total electricity demand over the next decade. However, companion policies including infrastructure investments and electric vehicle incentives enabled by carbon price revenue will have a more important effect.
- **In contrast, the electricity sector could influence outcomes in the transportation sector importantly** through electricity rate reform and strategic infrastructure investments. This strategy could accelerate the introduction of renewable energy and amplify the emissions reductions in the region.
- **If carbon pricing in transportation and electricity were linked the overall cost effectiveness of carbon pricing in the region would be improved but it would yield substantially less revenue for investments in transportation.** A linked program could achieve the same emissions reductions in the aggregate. However, the allowance price would remain at the RGGI price floor in a linked program.

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<sup>2</sup> The participating states include Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, Delaware, Maryland and Virginia, along with the District of Columbia.

<sup>3</sup> RGGI largely overlaps the TCI region. Virginia has issued a final regulation to join RGGI. Governor Wulf of Pennsylvania has issued an executive order directing the state Department of Environmental Protection to begin a process that would culminate in the state joining RGGI.

## How will expected electrification of transportation influence the national electricity market?

Electrification of transportation is happening already, including electrification of light duty vehicles for personal use, buses, and some delivery vehicles. Nationally, about 1.14 percent of new automobile sales are electric vehicles as of 2017.<sup>4</sup> However, there is considerable variation in expectations about the pace of electrification. At the national level, the Energy Information Administration's (EIA's) National Energy Modeling System (NEMS) provides a relatively modest forecast in their Annual Energy Outlook (AEO) 2020 report.<sup>5</sup> AEO finds that by 2050, 81 percent of light-duty vehicle sales will still consist of gasoline and flex-fuel vehicles. In contrast, the National Energy Renewable Laboratory (NREL) offers a range of projections in its Electrification Futures Study. NREL's more modest Reference case forecast, a lower bound, suggests that 11 percent of the light-duty vehicle (LDV) stock will consist of plug-in electric vehicles specifically by 2050.<sup>6</sup> The more ambitious forecast from NREL's High scenario anticipates an 84 percent LDV stock penetration of plug-in electric vehicles by 2050. Some other groups such as Bloomberg New Energy Finance (BNEF) suggest that the pace could be close to NREL's High forecast. BNEF's Electric Vehicle Outlook 2019 projects that by 2040, 57 percent of new passenger vehicle sales will be electric vehicles.<sup>7</sup>

## How will expected electrification of transportation influence the electricity market in the TCI region?

We first analyze outcomes in the absence of a carbon price by adjusting EIA's forecast to remove all demand for electricity for vehicles in the TCI region. In comparison to this 'No EV Baseline', NREL's modest Reference case in 2030 would yield 1.7 percent increase in total demand, and its ambitious High scenario would result in 9.5 percent increase in the TCI region, compared to a baseline with no electric vehicles.

TCI Region in 2030	NREL Modest Reference Case	NREL Ambitious High Case
<i>Change from the No EV Baseline</i>		
Total Electricity Demand	1.7%	9.5%
Electricity Sector Carbon Dioxide Emissions	7.9%	36.8%

**Table 1.** Electric Vehicle Demand for Electricity

<sup>4</sup> Xing et al. 2019; [https://media.rff.org/documents/WP\\_19-05\\_Leard.pdf](https://media.rff.org/documents/WP_19-05_Leard.pdf) (Table 1, Page 30).

<sup>5</sup> <https://www.eia.gov/outlooks/aeo/pdf/AEO2020%20Full%20Report.pdf> (Page 106).

<sup>6</sup> <https://www.nrel.gov/docs/fy18osti/71500.pdf>; pages xii and 43-45. See also Figure ES-5 for electricity's share of final energy consumption.

<sup>7</sup> <https://about.bnef.com/electric-vehicle-outlook/#toc-viewreport>

We examine potential outcomes in the electricity sector using RFF’s Haiku electricity market model, which solves for investment and operation of the sector over a twenty-three-year horizon. Increased demand will bring additional generating units into service. Emissions outcomes are affected by the RGGI program, but we find that by 2030 emissions are below the level that would result from full implementation of RGGI’s emissions containment reserve and the allowance price is at the price floor. Consequently, emissions vary in response to changes in electricity demand and generation. We find the advent of electric vehicles in the modest Reference case in the TCI region, even before the introduction of a carbon price, would lead electricity sector emissions to be 7.9 percent greater, and in the ambitious High case emissions they would be 36.8 percent greater compared to a scenario with no electric vehicles. This constitutes a 6-28 million metric ton increase in carbon dioxide emissions in the electricity sector in the TCI region relative to a 75 million metric ton (no-EV) baseline.

Activities by TCI are expected to further accelerate the introduction of electric vehicles relative to the scenarios described in Table 1. One pathway that would accelerate the use of electric vehicles is the change in gasoline prices that would accompany a carbon price. TCI has provided no indication of the level of a carbon price, so we make an independent assumption and examine a scenario that achieves a \$10 price (2018\$) per metric ton of carbon dioxide associated with transportation fuels that would be introduced in 2022. If the carbon price were transmitted through to a change in the price of fuels it would result in an increase of \$0.07 per gallon of gasoline, and an increase of \$0.08 per gallon of diesel.<sup>8</sup>

The change in the price of gasoline or diesel will lead to short run changes in vehicle miles traveled, and greater use of more efficient vehicles or alternative forms of transportation. In the long run it will affect vehicle purchase decisions.<sup>9</sup> In 2030, we assume the price of gasoline is \$3.00 per gallon (2018\$), rising to \$3.07 under a \$10 carbon price. Taking NREL’s ambitious High scenario as the result of revenue investment in the transportation sector and other companion policies to TCI, we calculate that the carbon price itself would yield an incremental increase of 1.7 percent above the NREL High case electric vehicle demand.<sup>10</sup>

We use the price elasticity to calculate the incremental increase in electricity demand due to the carbon price. Under the NREL High Case scenario, the introduction of a carbon price increases total electricity

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<sup>8</sup> About 17.68 pounds of carbon dioxide are produced by burning a gallon of gasoline with 10% ethanol content. At a price of \$10 per metric ton of carbon dioxide, this translates into an increase in the cost of gasoline of \$0.07 per gallon. Diesel has about 20.142 pounds of carbon dioxide per gallon with 10% ethanol content. A carbon price of \$10 per metric ton of carbon dioxide translates into \$0.08 per gallon of diesel.

<sup>9</sup> The best estimate we have found comes from a Norwegian study that suggests a cross-price elasticity of 0.62 for electric vehicles and 0.41 for plug-in hybrids (<https://www.toi.no/publications/the-demand-for-new-automobiles-in-norway-a-big-model-analysis-article35210-29.html>). This is the “cross-price elasticity of demand for electric vehicles with respect to the price of liquid fuels.” Most studies report cross price elasticities for electric vehicles with respect to price of gasoline cars (see [https://media.rff.org/documents/WP\\_19-05\\_Leard.pdf](https://media.rff.org/documents/WP_19-05_Leard.pdf), Pages 34 and 35, Tables 5 and 6).

<sup>10</sup> We assume a cross-price of elasticity for the demand of electricity in transportation with respect to the price of gasoline, inclusive of investments of carbon revenues that support electrification, equal to 0.6. This implies a 1 percent increase in the price of the transportation fuel leads to a 0.6 percent increase in consumption of electricity. An increase in the price of fuels will also lead to behavioral adjustments in the way people use their conventional vehicles. Generally, the literature suggests a 1 percent increase in the price of the fuel leads to a 0.15 percent reduction in consumption of the fuel, which is the own-price elasticity.

demand due to electric vehicles from 9.5 percent (Table 1) to 9.7 percent compared to the No EV Baseline in 2030. This RGGI allowance price remains at the price floor.

The introduction of electric vehicles could make electricity demand and prices more volatile if the demand for electricity for transportation was volatile. Transportation sector activity (measured in vehicle miles traveled) is affected by changes in the price of gasoline and by changes in economic activity. The price of gasoline, for example, has varied by over 250 percent in real terms from the lowest to the highest observed price in the last two decades.<sup>11</sup> Changes in total vehicle miles traveled could precipitate changes in electricity demand, either through electric vehicles driving a different amount or through changed revenue for investment in transportation electrification. The average change in vehicle miles traveled averaged over the period 1990 to 2018 was 2.5 percent per year. To investigate potential volatility in electricity demand we consider an arbitrary minimum and maximum scenario in which electric vehicle miles traveled varies by 2.5 percent from an annual expectation.

TCI Region in 2030	Low Vehicle Miles Traveled	High Vehicle Miles Traveled
<i>Change from Expected VMT Case</i>		
Electricity Demand	-0.2%	0.2%
Electricity Sector Carbon Dioxide Emissions	-0.6%	2.6%

**Table 2.** The Effect of a \$10 Carbon Price on Electricity Demand with Variation in Vehicle Miles Traveled Under the NREL High Case

The changes in electricity demand and carbon dioxide emissions compared to expected values are small, as shown in Table 2. Emissions in the TCI region fall by 0.5 million tons in the low case and increase by 2.5 million tons in the high case, compared to expected emissions of 102.47 million tons under the carbon price with the expected level of vehicle miles traveled. In all these examples the RGGI allowance price remains at the price floor.

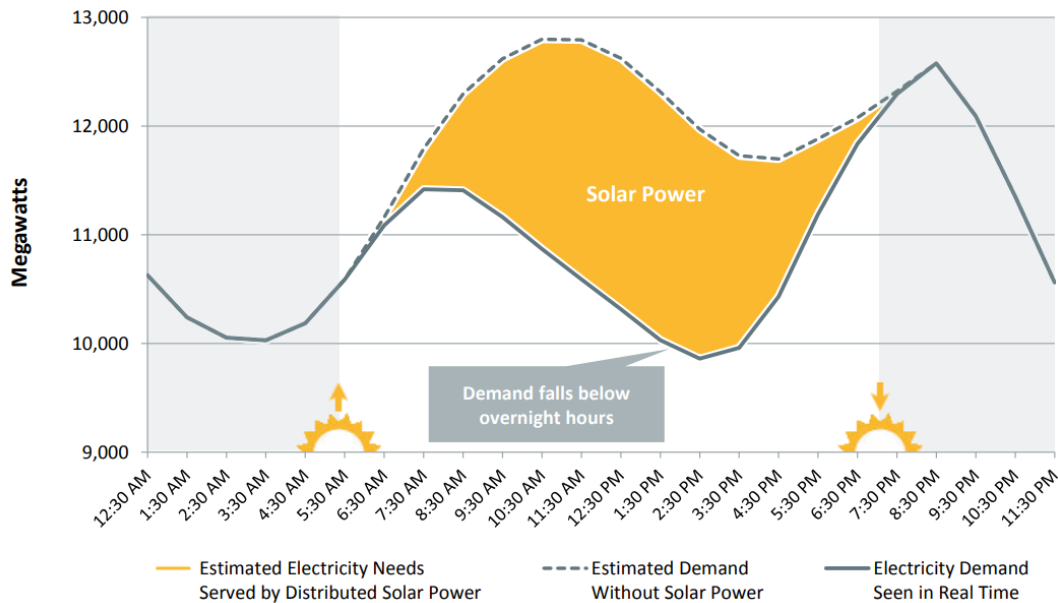
### How might changes in the electricity market accelerate decarbonization of transportation?

The environmental and resource implications of electrifying transportation depend on the time of day that vehicles charge, because different resources come into service at different times of day to meet the bump in electricity demand. Although some utilities are beginning to offer discounts for charging at times of abundant resource availability and low wholesale power prices, this innovation is only incremental and not widespread. Current charging profiles appear to be influenced largely by convenience with little attention given to the time of charging.

<sup>11</sup> <https://www.energy.gov/eere/vehicles/fact-915-march-7-2016-average-historical-annual-gasoline-pump-price-1929-2015>.

Ross (2019) compares charging schedules for electric vehicles and concludes that they can have significant environmental implications.<sup>12</sup> Under an “intermediate” scenario, Ross finds that non-emitting resources could provide 8-20 percent of demand in the Northeast region, and 24-55 percent in the Southeast region in 2050, depending on the time profile of charging.

The time profile of vehicle charging could be affected greatly by policies that take shape at the state level including electricity rate reform. Borenstein and Bushnell (2019) examine the efficiency of electricity prices and find that prices in general do not reflect social marginal costs. In regions of the country where electric vehicles have so far had the greatest market penetration – in California and the northeast – electricity prices tend to be greater than social marginal costs. Social marginal cost involves the incremental cost of providing electricity services, including fuel costs, labor costs, and environmental costs. These parts of the nation’s electricity grid have lower marginal social cost in part because these regions are relatively clean, causing relatively lower environmental damages. Over time of the day, the deviation of electricity price from social marginal cost can be even more pronounced because the electricity price includes fixed costs associated with the electricity grid. This deviation of electricity price from social marginal cost is a substantial obstacle to the electrification of transportation, especially because as the authors point out, gasoline prices are below the social marginal cost of gasoline consumption. Moreover, in many regions where solar energy is abundant, an incremental megawatt-hour of electricity demand in some daytime hours has nearly zero social marginal cost.



**Figure 1:** Historic Dip New England in Midday Demand with Record-High Solar Power Output on April 21, 2018.

[https://www.iso-ne.com/static-assets/documents/2019/02/20190220\\_pr\\_state-of-the-grid\\_presentation\\_final.pdf](https://www.iso-ne.com/static-assets/documents/2019/02/20190220_pr_state-of-the-grid_presentation_final.pdf)

<sup>12</sup> <https://nicholasinstitute.duke.edu/publications/emissions-benefits-electric-vehicles-influencing-electricity-generation-choices> (Page 38, Figures 28-29).

Among various reform possibilities that could more closely align electricity prices with marginal social costs is the possibility of separate metering for electric vehicles. Further, vehicles do not require the full-service reliability that is embodied in the sunk costs of the grid as it is currently constructed because they may need to be charged only once a week, when it is advantageous to do so. While vehicles impose some new distribution costs on the grid, the flexibility inherent in vehicle demand for electricity might suggest they could be exempt from obligations for cost recovery of the incumbent grid. In fact, the expansion of resources that their electricity demand entails may enhance reliability for other inflexible sources of demand. In the context of overarching policy aimed at mitigating carbon dioxide emissions, retail electricity rate reform might be structured to encourage the bulk of charging from renewable resources. The Independent System Operator in New England illustrates a *loon version* of the famous California duck curve,<sup>13</sup> showing that solar abundance can lead to daytime levels of demand that are below nighttime levels (Figure 1).

TCI Region in 2030	NEMS Charging Profile	Daytime Profile
Wind and Solar generation (TWh)	223	271
Electricity sector carbon dioxide emissions (million tons)	102	87

**Table 3.** The Timing of Vehicle Charging Affects Renewable Generation in the TCI Region

Using the NREL High case for electric vehicle penetration and the carbon price as a point of departure, we revisit this question looking over the next decade by varying the time profile of charging and its effect on the quantity of renewable generation. The NEMS default charging profile is reported in the first column of Table 3. The NEMS charging profile happens chiefly at night, which in the Haiku model translates to baseload hours when coal, nuclear, and wind are the most available generation types. For contrast, we construct a scenario we label daytime in which most of the charging occurs during Haiku’s mid load hours when more solar is available. This scenario yields 22 percent more renewable generation and 15 percent fewer carbon dioxide emissions. Policies in the electricity sector that aligned electricity prices with marginal social costs, coupled with strategic investment of carbon price revenues in infrastructure for vehicle charging where cars are located in the daytime could substantially amplify the environmental benefits of electric vehicles.

### What might be the RGGI and TCI carbon market outcomes, and what might happen to electricity prices, if the TCI and RGGI carbon markets were linked?

Carbon markets in separate jurisdictions have been linked in the EU Emissions Trading System, in the Western Climate Initiative and in RGGI. Advantages of linking include reduced chance of leakage, administrative simplicity, stability of prices, effort-sharing and especially risk-sharing (Doda, Quemin, and Taschini 2019). Effort-sharing results from the heterogeneity in abatement technologies and

<sup>13</sup> [https://en.wikipedia.org/wiki/Duck\\_curve](https://en.wikipedia.org/wiki/Duck_curve)

emissions reduction goals. Risk-sharing is attributable to the pooling of risk associated with uncertainty affecting each program's demand for emissions. Moreover, linking sends a signal onto the national and international stage that jurisdictions are cooperating, and carbon pricing is expanding in scope, enabling other jurisdictions to consider similar policies.

To consider a linked market, we represent how emissions and carbon allowance prices in the TCI are related. Emissions reductions in the TCI carbon market reflects the ability for accelerated electrification, other changes in vehicle purchase decisions, plus uptake of other behavior such as changing of driving patterns and use of public transit. Using information about electric vehicles and hybrids, we estimate that a one dollar change in the carbon price (due to linking) would translate into 0.0012 percent change in the use of electric vehicles.<sup>14</sup>

Linking markets with different initial carbon prices will tend to result in a price between the prices in two independent markets.<sup>15</sup> In the jurisdiction that purchases emissions allowances, we expect the price to fall, and in the jurisdiction that sells allowances we expect the price to rise. We examine the NREL High case with a TCI scenario with a policy-determined carbon price of \$10 per metric ton and an initial RGGI carbon price of \$2.05 per short ton of carbon dioxide at the price floor (\$2.26 per metric ton). Implementation of a linked market yields the same total emissions outcome across the two programs. Emissions allowances flow from electricity to transportation, resulting in lower reductions in the transportation sector and higher reductions in the electricity sector than with unlinked programs. However, the allowance price does not rise in RGGI, but remains at the RGGI price floor of \$2.05 per short ton, because there are sufficient opportunities to reduce emissions at this price in the electricity sector that are equivalent to the emissions reductions in the transportation sector in the unlinked program. This outcome results in a dramatic reduction in revenue to the transportation sector.

### Concluding thoughts

TCI policies will impact the transportation sector through more than just the carbon price. TCI investments in electric vehicle infrastructure or in vehicle incentives will increase electrification of the transportation sector, while TCI investments in public transit, walkability, and housing may change how people approach transportation altogether. We capture some electrification effects by employing NREL's high electrification case as a point of departure for the carbon price effects, but we cannot capture cultural shifts in transportation from public transit and land-use planning. Our purpose, however, is not to evaluate the impact of TCI on the transportation sector but instead to evaluate its impact on the electricity sector. In this context, we expect the results to be generally accurate and robust to more detailed analysis of TCI.

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<sup>14</sup> We assume the cross-price elasticity of electric vehicles with respect to the gasoline price is 0.62 and with respect to the diesel price is 0.41. We assume the price of gasoline in the unlinked program is \$3.07 in 2030 (2018\$).

<sup>15</sup> Note RGGI allowances are denominated in short tons and TCI allowances are assumed to be in metric tons.