Distribution System Investments to Enable Medium- and Heavy-Duty Vehicle Electrification

A Case Study of New York

Prepared for the Environmental Defense Fund

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EXECUTIVE SUMMARY

Reducing greenhouse gas emissions from medium- and heavy-duty vehicles—including tractor trailers, delivery trucks, buses, refuse trucks, and large pickup trucks and vans—will be necessary for the United States to meet its climate goals and will involve electrifying the majority of these vehicles. However, large-scale medium- and heavy-duty vehicle (MHDV) electrification will require distribution system and site upgrades to support higher load on the grid and accommodate installation of charging stations. Currently, the costs of these upgrades fall largely on individual fleet owners. This may hinder electrification, especially for fleet owners who already face challenging economics to electrify their fleets. One way to support the rapid adoption of electric MHDVs would be to socialize certain distribution system and site infrastructure upgrade costs through an electric vehicle make-ready program. The net impact on electricity ratepayers from such a program will depend on whether the increased distribution revenue from MHDV electricity sales can offset the costs of distribution system upgrades (including make-ready programs).

In this analysis, we examine the impact on rates of a MHDV make-ready program in two areas of New York: Con Edison's service area in New York City and the western part of National Grid's service territory in upstate New York. We calculate the cost of the distribution system upgrades necessary to support 100 percent electric MHDV sales by 2045, consistent with state targets, as well as make-ready program costs. We then compare these costs to the expected revenues generated from MHDV electrification under existing utility tariffs.

We find that a make-ready program would have a neutral-to-beneficial impact on rates in both utility service areas for the period 2023–2045. With unmanaged charging and a 3 percent discount rate, the net revenues in Con Edison's service territory total $820 million, potentially reducing costs for all ratepayers. In National Grid's territory, we find that unmanaged charging results in close to zero net revenue ($320,000) during the same period. These net revenues remain positive under a higher discount rate of 7 percent.

Under a managed charging scenario that decreases each vehicle's peak load by 20 percent, the cumulative net revenue totals $690 million for Con Edison and $89 million for the western part of National Grid at a 3 percent discount rate. Again, the net revenues remain positive under a higher discount rate of 7 percent.

These positive net revenue results imply that socializing the costs of make-ready and distribution system upgrades necessary to meet New York State's MDHV electrification targets are unlikely to cause ratepayer bills to increase in either of the utility service areas studied, due to being offset by the revenues contributed by MHDVs over the same period.

1. INTRODUCTION

The United States will need to reduce greenhouse gas emissions from its vast array of tractor trailers, delivery trucks, buses, refuse trucks, and large pickup trucks and vans to meet its climate goals. In 2019, these medium- and heavy-duty vehicles (MHDV) accounted for over one-fifth of U.S. transportation sector emissions, equivalent to 7 percent of total U.S. greenhouse gas emissions.[1] The diesel internal combustion engines that currently power nearly all MHDVs in the United States release both carbon dioxide and toxic air pollutants, with disproportionate burdens in communities of color and low-income communities.[2]

To reduce the climate and public health harms from MHDVs, zero emissions vehicles must replace internal combustion engine vehicles. For the majority of market segments, battery electric vehicles are the most practical zero emission technology due to their cost-effectiveness, technological maturity, and scalability.[3] In 2020, 17 states and the District of Columbia signed a Memorandum of Understanding committing to accelerating MDHV electrification.[4] California also adopted its Advanced Clean Trucks (ACT) rule in 2020, setting annual requirements for zero emission MHDV sales for vehicle model years 2024 through 2035.[5] Six additional states have since joined California in adopting this regulation.[6]

In order for states to successfully meet their MHDV electrification targets, they must address the cost of electrification so that fleet owners see an economic advantage to electrifying their MHDVs. One under-studied but sizeable group of costs facing many fleet owners is the distribution system and site upgrades necessary to support added electric load from MHDV charging. At the charging site, vehicle load may necessitate new meters, panels, transformers, and conductors. Upstream, utilities may need to upgrade

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[1] Ledna, C, Muratori, M, Yip, A, Jadun, P, and Hoehne, C. 2022. *Decarbonizing Medium- & Heavy-Duty On-Road Vehicles: Zero-Emission Vehicles Cost Analysis*. NREL. Available at: https://www.nrel.gov/docs/fy22osti/82081.pdf.

[2] Fleming, K, Brown, A, Fulton, L, and Miller, M. 2021. "Electrification of Medium- and Heavy-Duty Ground Transportation: Status Report." *Current Sustainable/Renewable Energy Reports* 8, 180-188. https://doi.org/10.1007/s40518-021-00187-3.

[3] Two additional technologies will play a role in certain market segments: Fuel cell hydrogen vehicles will likely offer cost advantages for some long-haul transport, and liquid biofuels can help reduce emissions from legacy internal combustion engine vehicles (Ledna et al. 2022), although the limited supply of low-carbon biofuels precludes their widespread adoption.

[4] *Multi-State Medium- and Heavy-Duty Zero Emission Vehicle Memorandum of Understanding*. 2020. Available at: https://www.nescaum.org/documents/mhdv-zev-mou-20220329.pdf.

[5] California Air Resources Board. 2021. *Advanced Clean Trucks Fact Sheet*. Available at: https://ww2.arb.ca.gov/resources/fact-sheets/advanced-clean-trucks-fact-sheet.

[6] The states that have adopted the ACT Rule are California, Massachusetts, New Jersey, New York, Oregon, Vermont, and Washington.

feeder conductors to safely serve additional load, and at the substation, they may need to add feeder breakers and increase the capacity of step-down transformers.[7]

Which party is responsible for each type of cost strongly affects how cost-effective electrification appears to fleet owners. Currently, in addition to the cost of the vehicles and chargers themselves, fleet owners are, in most states, individually responsible for much of the on-site infrastructure (including transformers, meters, service lines, and panels). If the additional load from their EVs would overload upstream infrastructure, the utility typically assigns them these costs as well. This results in large upfront costs that are a substantial barrier to MHDV electrification.

One way to increase the adoption of electric MHDVs would be to socialize all or a larger portion of the customer site and distribution system infrastructure costs. By recovering these costs from all utility customers, the cost of MHDV electrification would be substantially reduced for vehicle owners. The overall impact on other electricity ratepayers would depend on whether the program brought in more revenue through increased electricity sales than it cost the utility.

In this study, we estimate the distribution system investment, including site-level costs, necessary to meet vehicle electrification targets in New York, which has a legislative goal of 100% zero emission MHDV sales by 2045.[8] We also estimate the likely impact on ratepayers if these costs are socialized to all utility customers, including a scenario with unmanaged charging and one with managed charging. The analysis includes both New York City and a representative region in upstate New York to capture the differing infrastructure needs of urban and rural areas.

2. METHODS

2.1. Non-MHDV load projections through 2045

This study includes two regions of New York: Con Edison's service area, which encompasses New York City and most of Westchester County, and the western part of National Grid's service area, which includes portions of Allegany, Cattaraugus, Chautauqua, Erie, Genesee, Niagara, Orleans, Livingston, and Wyoming Counties. There are no statewide reporting requirements for several key datasets necessary for this analysis, including long-term load projections, the locations of MHDVs, and projected load from electric MHDV charging. As a result, we found it necessary to tailor our analytical approach to each utility based on the available data. Throughout the analysis, we strove to make all calculations for Con

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[7] Borlaug, B, Muratori, M, Gilleran, M, Woody, D, Muston, W, Canada, T, Ingram, A, Gresham, H, and McQueen, C. 2021. "Heavy-duty truck electrification and the impacts of depot charging on electricity distribution systems." *Nature Energy* 6, 673-682. https://doi.org/10.1038/s41560-021-00855-0.

[8] New York Consolidated Laws § 19-0306-b (2022).

Edison and National Grid as parallel as possible while accounting for nonuniformities in the data published by each.

We began by projecting load growth in both utility service areas in the absence of vehicle electrification. For Con Edison, our starting point was substation-level hourly load projections through 2023 (available on the Con Edison Hosting Capacity database[9]) and the 10-year compound annual growth rates from Con Edison's 2020 Distributed System Implementation Plan, which include factors such as heating electrification and deployment of distributed generation.[10] We assumed that these growth rates would remain constant after 2023 in order to project hourly load at each substation through 2045 in the absence of MHDV electrification.

For National Grid, we used feeder-level forecasts published on the Company's data portal through 2026.[11] National Grid does not publish 10-year load forecasts as part of its Distributed System Implementation Plan, so after 2026, we calculated summer and winter load-growth rates using coincident peak demand projections from the New York Independent System Operator (NYISO) gold book for Zones A and B[12] (adjusted to remove the vehicle load included in those forecasts). We then applied these growth rates uniformly to all feeders.

Our analysis focuses on substations in Con Edison's service area rather than feeders because the networked design of Con Edison's distribution system means that the load growth on individual feeders cannot be projected meaningfully, while National Grid's predominantly radial feeders lend themselves to disaggregated analysis.

2.2. Number and location of electric vehicles

We modeled electric vehicle sales following the ACT rule trajectory through 2035 and assumed a linear trajectory post-2035 to meet New York's 2045 target of 100 percent zero emissions MHDV sales. Figure 1 shows the resulting sales trajectories, and Figure 2 shows the stock of electric MHDVs in each service area.

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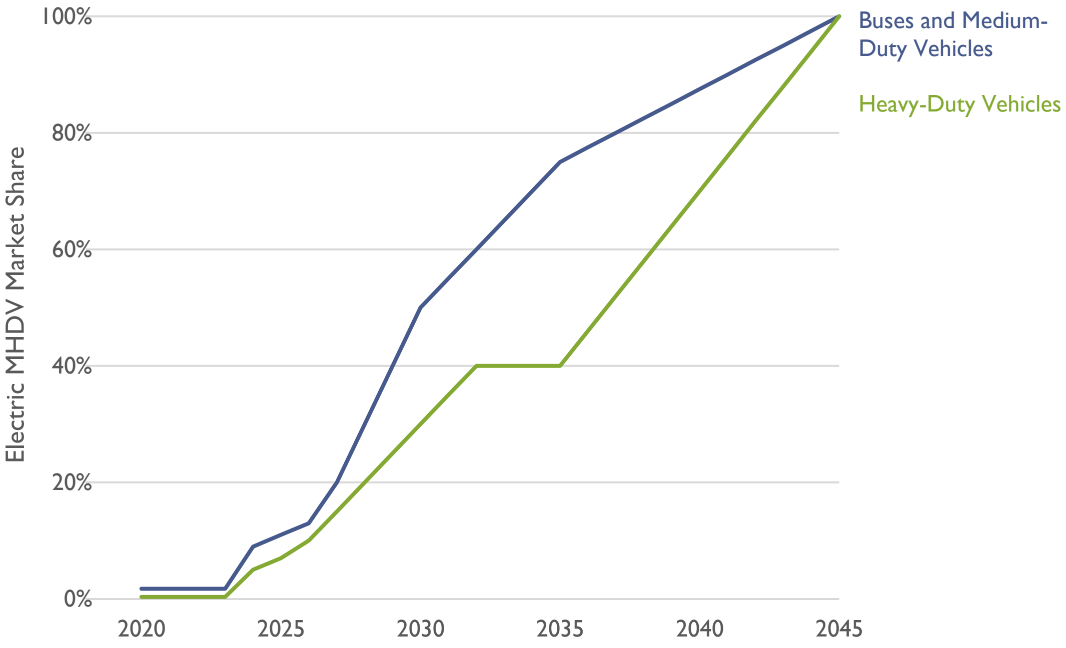
[9] Con Edison Hosting Capacity Web Application. Available at: https://www.coned.com/en/business-partners/hosting-capacity.

[10] Consolidated Edison. 2020. *Distributed System Implementation Plan*. Available at: https://www.coned.com/-/media/files/coned/documents/our-energy-future/our-energy-projects/distributed-system-implementation-plan.pdf.

[11] National Grid New York System Data Portal. Available at: https://ngrid.portal.esri.com/SystemDataPortal/NY/index.html.

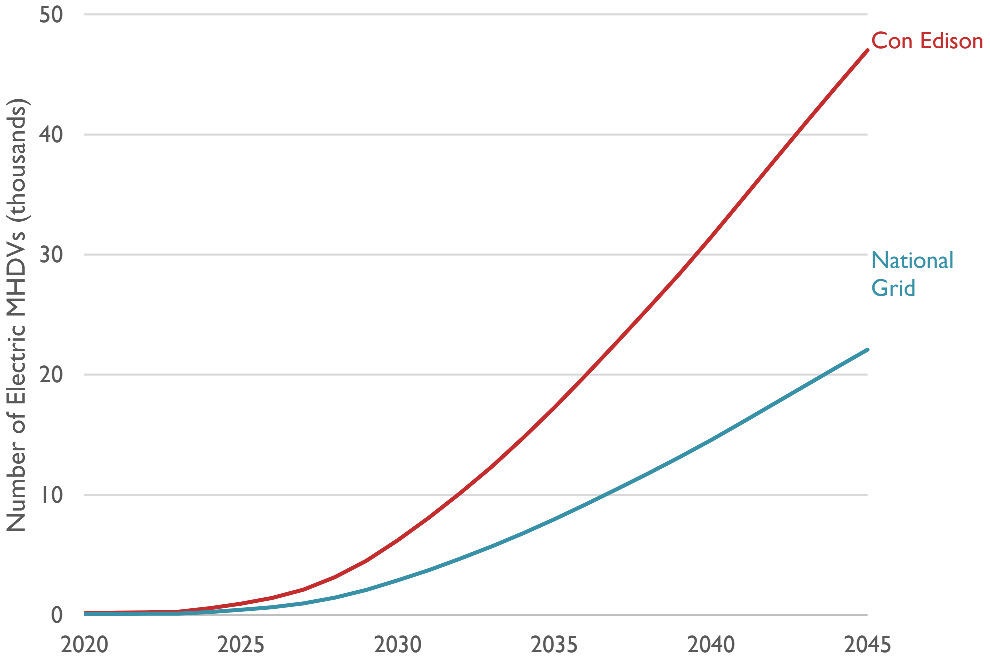
[12] New York Independent System Operator (NYISO). 2022. *2022 Load & Capacity Data: Gold Book*. Available at: https://www.nyiso.com/documents/20142/2226333/2022-Gold-Book-Final-Public.pdf/cd2fb218-fd1e-8428-7f19-df3e0cf4df3e.

Figure 1. Projected market share of electric MHDVs in New York State



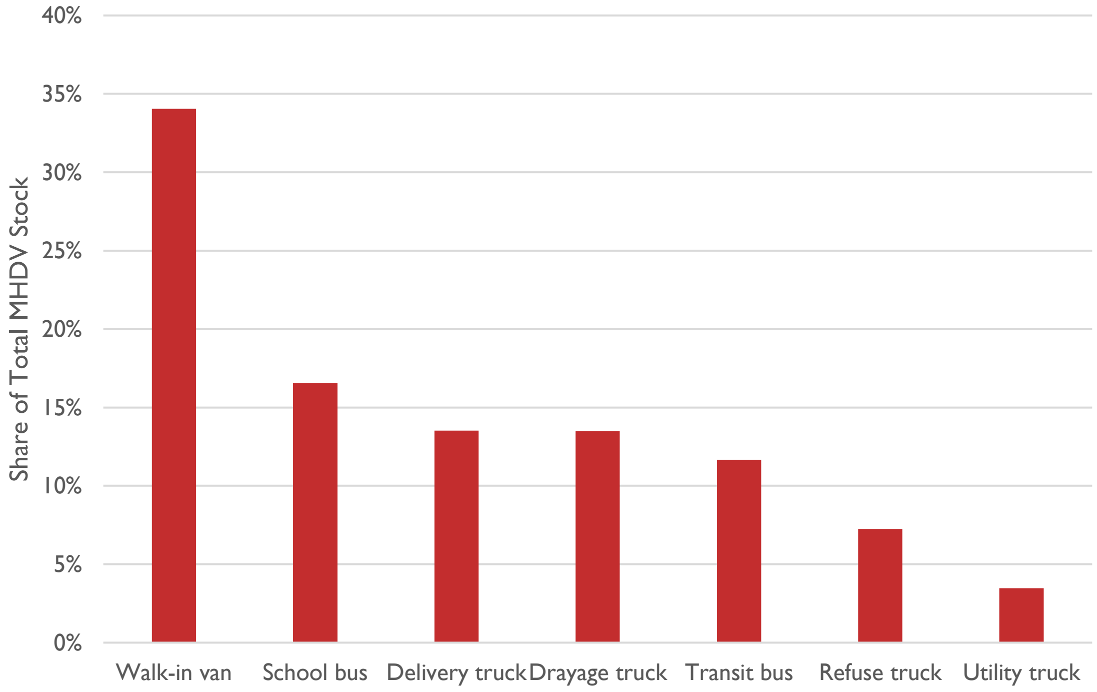
Notes: The sales trajectory follows ACT rule targets through 2035 and assumes a linear trajectory post-2035 to reach 100 percent electric vehicles sales by 2045.

Figure 2. Projected electric MHDV stock in each utility service area



Con Edison provided us with the current number of internal combustion engine utility trucks, refuse trucks, delivery trucks, drayage trucks, school and transit buses, and walk-in vans served by each of its substations. We then scaled these values by the forecasted number of electric MHDVs in service each year, assuming that electric vehicles will charge at the same locations that internal combustion engine vehicles are currently located and that the relative number of vehicles at each location would stay constant through 2045. Figure 3 shows the breakdown of vehicles by type in Con Edison's service area.

Figure 3. Vehicle types in Con Edison's service area



Notes: Compared to National Grid, Con Edison has a larger proportion of medium-duty vehicles and transit buses.

For National Grid, we focused on four categories of vehicles: warehouse vehicles (consisting of both delivery trucks and tractor trailers), school buses, transit buses, and "other MHDVs" (a composite of remaining vehicle types that includes utility trucks, dump trucks, flatbeds, and private buses). Using a dataset of vehicle registrations in New York,[13] we determined the current number of each vehicle type in National Grid's service area. Figure 4 shows the breakdown of vehicles by type.

To assign the vehicles to locations, we allocated delivery trucks and tractor trailers to warehouses in proportion to warehouse rentable area. We assumed school buses would charge at schools and that the

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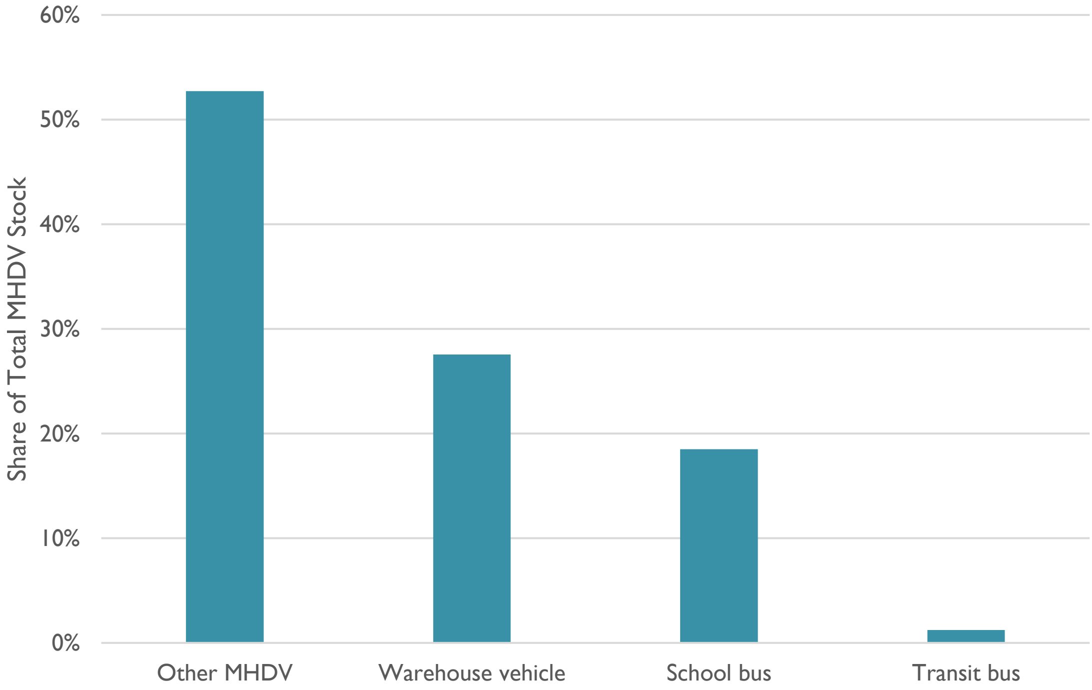
[13] Open Data NY. 2022. "Vehicle, Snowmobile, and Boat Registrations." Available at https://catalog.data.gov/dataset/vehicle-snowmobile-and-boat-registrations.

number of buses at each school is proportional to the number of students.[14,15] We located transit buses at transit bus depots, using data from the Federal Transit Administration,[16] and we divided vehicles in the "other MHDV" category evenly across feeders. This yielded a dataset with an estimated number of each type of vehicle located at each feeder. Similar to Con Edison, we assumed that electric vehicles will be added at each feeder in proportion to the internal combustion engine vehicles currently located there.

Figure 4. Division of vehicle types in the western portion of National Grid's service area



Notes: Compared to Con Edison, National Grid has a higher proportion of heavy-duty trucks such as tractor trailers.

2.3. Peak load projections including MHDVs

We used MHDV charging load profile data provided by Lawrence Berkeley National Laboratory to estimate the added load from electric MHDVs at the substation or feeder level.[17] These load curves represent aggregate load curves for vehicle type over a 24-hour period. Where necessary, we developed

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[14] NYS Education Department and NYS GIS Program Office. 2017. "NYS Schools and School District Boundaries." Available at http://gis.ny.gov/gisdata/inventories/details.cfm?DSID=1326.

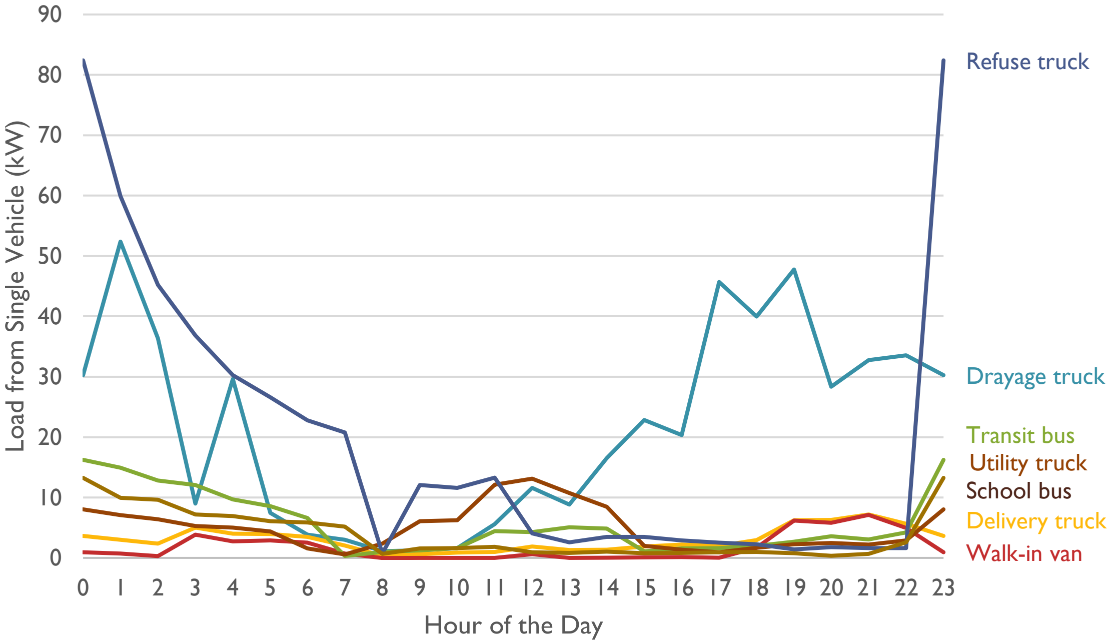
[15] NYS Education Department. 2022. "Public School Enrollment: School Enrollment – All Students." New York State Education Department. Available at: https://www.p12.nysed.gov/irs/statistics/enroll-n-staff/home.html.

[16] Federal Transit Administration. 2020. *National Transit Database*. Available at: https://www.transit.dot.gov/ntd/what-national-transit-database-ntd-program.

[17] Lawrence Berkeley National Laboratory. HEVI-Pro load profiles. Provided in August 2022.

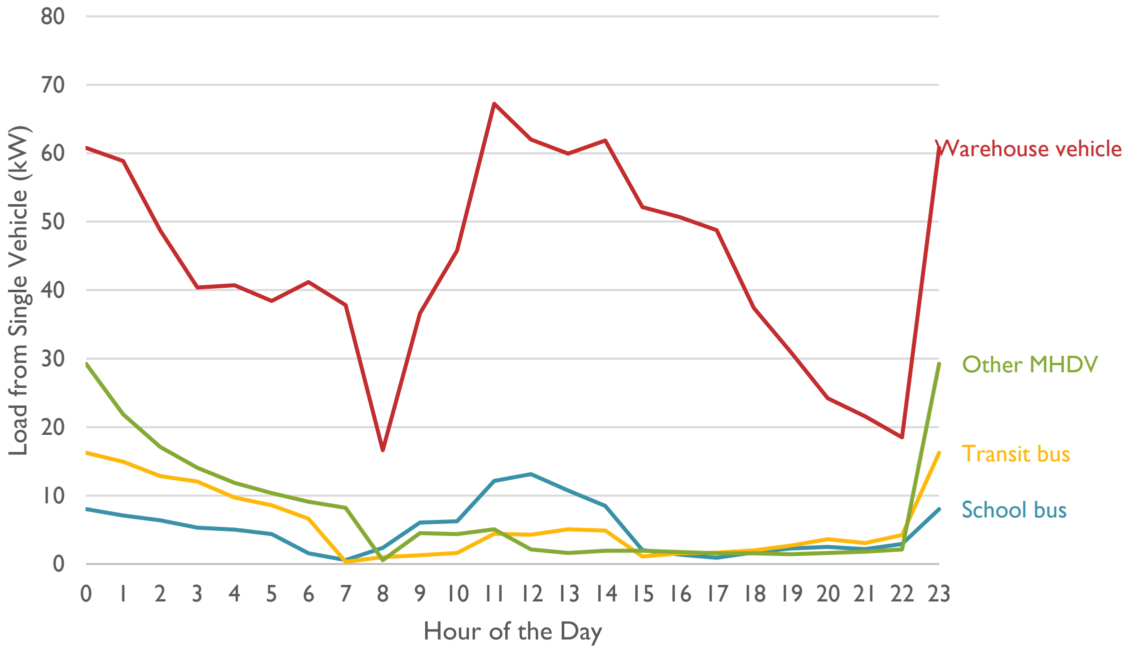
composite load curves weighted by the frequency of each vehicle type (Figure 5 and Figure 6). The composite load curves account for the differing demand characteristics of vehicles within each type (e.g., the warehouse vehicle composite load curve accounts for the demand patterns of both delivery trucks and tractor trailers). We then multiplied these load curves by the projected number of vehicles in each year and added the MHDV hourly load to the non-MHDV hourly load projections from Section 2.1. This enabled us to identify the projected hour and magnitude of peak load on each feeder in each year through 2045.

Figure 5. Load profiles for electric MHDVs in Con Edison's service area



Notes: Figure shows the aggregate effect of each vehicle type at the substation level.

Figure 6. Load profiles for electric MHDVs in National Grid's service area



Notes: Figure shows the aggregate effect of each vehicle type at the feeder level.

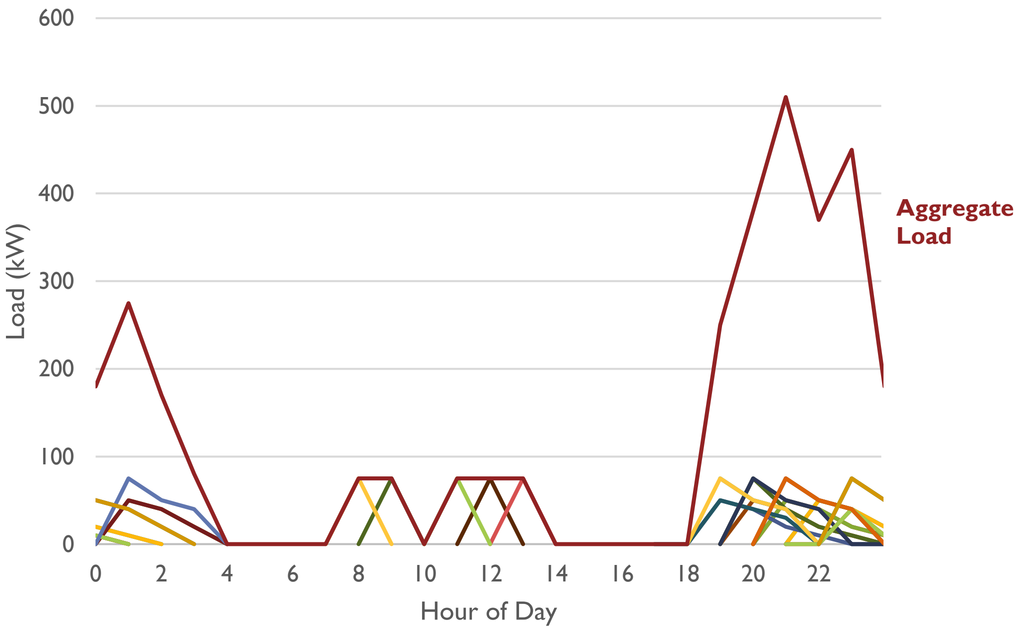
2.4. Site-level load diversity

To determine the demand imposed on the grid at the site level, we first considered the impact of load diversity. Load diversity accounts for the fact that vehicles at a site are unlikely to all begin charging at the same time (or at the same battery state of charge), and consequently the site-level peak demand will be less than the sum of each individual vehicle's peak demand. Load diversity generally increases as the number of vehicles at a site increases. Thus, while an individual vehicle's peak demand may be 50 kW (kilowatts), a site with four vehicles may only have an aggregate peak demand of 120 kW.

The load curves in Figure 5 and Figure 6 reflect the aggregate load of numerous vehicles and were thus applied at the substation or feeder level. Individual sites will usually have lower load diversities because vehicles at the same site tend to operate on similar schedules and charge at the same times of day. To account for this, we modified the aggregate load curves to reflect the lower load diversity at individual sites.

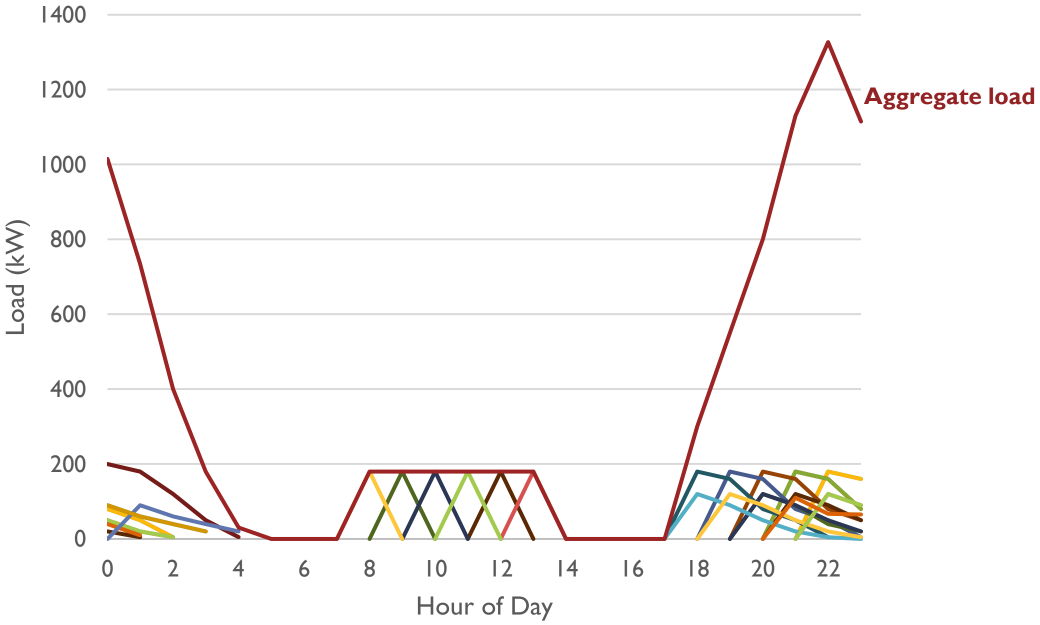
Data on site load diversity is limited, so we developed reasonable values by estimating load profiles for 20 individual vehicles at a site and then aggregating these values into a site load curve. We developed estimated site-level load profiles for Con Edison's territory and National Grid's territory separately to account for the different types of vehicles in each territory. Specifically, we used the estimated average daily vehicle energy consumption for each utility to estimate the average charger capacity required to accommodate the forecasted MHDVs. The resulting estimated load curves for sites with 20 vehicles are shown in Figure 7 for Con Edison and Figure 8 for National Grid.

Figure 7. Estimate of site load diversity in Con Edison's service area



Notes: Figure shows both the load from individual vehicles and the aggregate load from all 20 vehicles.

Figure 8. Estimate of site load diversity in National Grid's service area



Notes: Figure shows both the load from individual vehicles and the aggregate load from all 20 vehicles.

2.5. Distribution investment cost

To estimate the cost of system upgrades, we divided the investment costs into two categories: incremental distribution system upgrades and make-ready infrastructure. The incremental system upgrade costs include upstream sections of the distribution system such as substations. The make-ready costs include downstream infrastructure, such as customer panels and conductors (but not the vehicle chargers themselves) and utility distribution facilities between the substation and meter. The boundary between these two categories of costs is not clear-cut, but including both quantities helps to avoid undercounting costs.

We calculated incremental system upgrade costs using Con Edison and National Grid's demand reduction value (DRV) and locational system relief value (LSRV) (Table 1). DRV captures the cost of increasing peak loads and LSRV captures the cost of adding load in congested areas. We compared the annual peak load at each substation or feeder to its capacity. For substations or feeders where peak load did not exceed capacity during the study period, we multiplied the MHDV load by the DRV value to estimate the increased costs associated with accommodating additional load from MHDVs. For substations where load exceeded capacity during the study period, we multiplied the incremental MHDV load by the sum of the DRV and LSRV values for each year in which a capacity upgrade would be required.

Because National Grid's service area has a lower population density than Con Edison's, it has a larger proportion of feeders with only a few vehicles—by 2045, the median number of vehicles per feeder is only 13. As a result, many sites will likely have lower load diversity than Figure 8 would suggest. To account for this lower load diversity at sites with fewer than 36 vehicles, we scaled up the incremental system costs in inverse proportion to the number of vehicles at each site. (We determined the scaling factor through linear interpolation from the load diversity of one vehicle and the estimated load diversity of 20 vehicles. The factor decreases to one when a site has 36 vehicles.) For sites with only one vehicle, we increased the incremental system costs by a factor of five.

To determine the make-ready costs, we estimated average make-ready costs per vehicle in upstate and metro New York using cost estimates from the New York Department of Public Service,[18] which are the most up-to-date cost estimates publicly available for New York. We combined the New York-specific cost estimates with Lawrence Berkeley National Laboratory's projected charger capacities for California, the only state for which data was available[19] (Table 1). Combining these datasets required several simplifying assumptions, including that cost per charger is proportional to charger capacity and that all sites within a utility service area use the same mix of charger capacities. For National Grid, we assumed that the weighted average charger capacity per vehicle will be 189 kW, consistent with the California

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[18] New York Department of Public Service. 2020. *Staff Whitepaper Regarding Electric Vehicle Supply Equipment and Infrastructure*. Available as document 454 at https://documents.dps.ny.gov/public/MatterManagement/CaseMaster.aspx?MatterSeq=56005.

[19] Lawrence Berkeley National Laboratory. HEVI-Pro load profiles. Provided in August 2022.

dataset. For Con Edison, the average daily vehicle energy demand is only 150 kilowatt-hours, so we instead used an average charger capacity per vehicle of 64 kW (based on our site analysis) and scaled make-ready costs accordingly.

We then assumed that utilities would recover make-ready costs over the equipment’s useful lifetime, consistent with other distribution assets. We used a book life of 20 years and weighted average cost of capital of 7 percent to calculate the revenue requirement in each year.

We omitted wholesale market transmission and generation costs because these costs tend to be passed through directly to large customers based on the actual costs they impose on the grid, so they do not impact ratepayers more broadly.

Table 1. Make-ready and incremental system upgrade costs in Con Edison and National Grid service areas

	Con Edison	National Grid (western region)
Average charger capacity (kW/vehicle)	64	188
Make-ready cost ($/vehicle)	$36,350	$63,420
DRV ($/MW)	$199,400	$61,440
LSRV ($/MW)	$140,760	$30,720

Notes: Make-ready costs shown are the total cost per vehicle, prior to amortization. We scaled the DRV and LSRV values in National Grid as described above.

2.6. MHDV revenue

In addition to infrastructure upgrade costs, we calculated the additional revenue that Con Edison and National Grid would collect through distribution rates as a result of MHDV electrification. In New York, each utility recovers distribution revenue for large customers primarily through demand charges. For this portion of the analysis, we used the estimated site-level billing determinants (energy and demand) in each month and year. The number of substations or feeders with electric MHDVs in each year provides a lower bound on the number of sites. We combined this data with the total number of electric MHDVs in each year, adjusted so that the number of vehicles per site grows monotonically and never exceeds 50 (Figure 9). We then calculated the number of sites with electric MHDVs (Figure 10). In Con Edison’s territory, this number of vehicles at each substation grows to 50 by 2029, after which we assume that there are multiple sites per substation. In National Grid’s territory, the number of vehicles per feeder never grows beyond 26, so we assume that there is at most one vehicle site per feeder.

Figure 9. Average number of vehicles per site with electric MHDVs in each utility service area

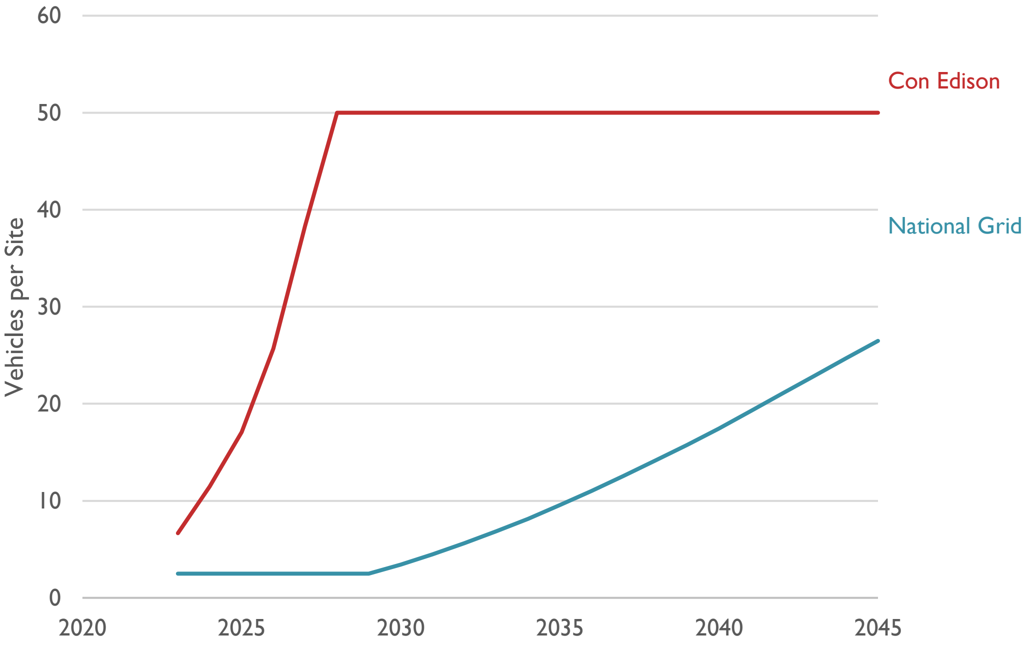
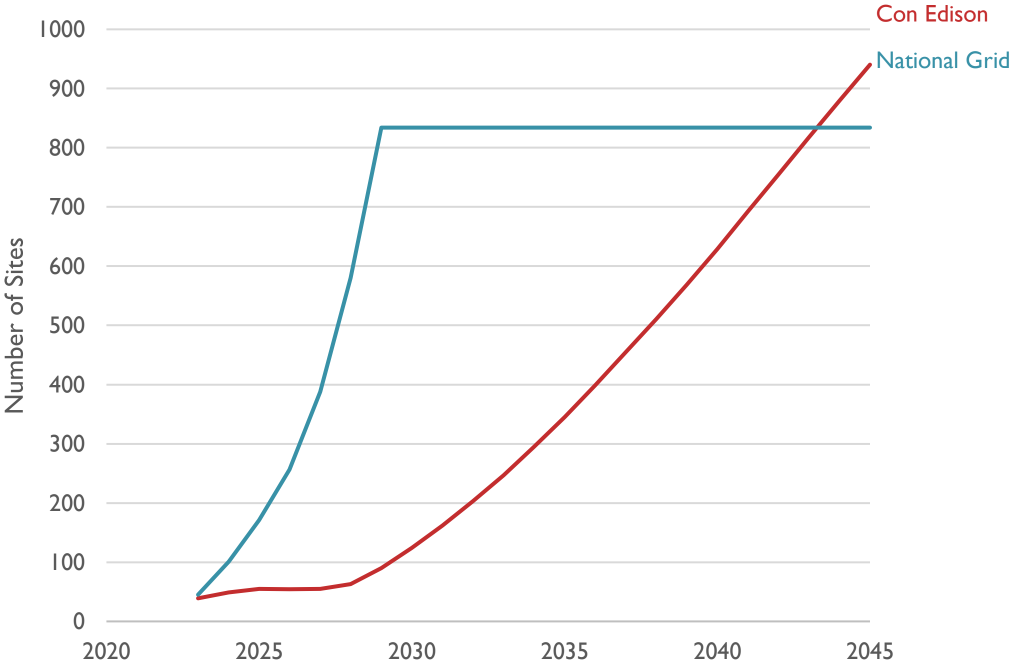


Figure 10. Number of sites with electric MHDVs in each utility service area



Notes: After 2029, we assume that additional electric MHDVs in National Grid's territory will be added to existing sites, since the number of vehicles per site never exceeds 50 (Figure 9).

Based on the number of vehicles and the estimated site-level load diversity, we estimated the peak demand at each site, as well as the energy consumed. For example, we estimated that each vehicle would require, on average, a charger capacity of 64 kW per vehicle in Con Edison's service area (Table 1). This means that a site with 50 vehicles could in theory draw 3.2 megawatts (MW) if every vehicle simultaneously demanded 100 percent of its charger capacity. However, the load diversity of 2.5 implies that the maximum demand per site will be closer to 1.3 MW (3.2 MW/2.5 = 1.3 MW), because actual vehicle demand will be staggered. Similarly, the average charger capacity per vehicle in National Grid's territory was estimated to be 188 kW, but with a load diversity of 2.8, each vehicle only contributes 67 kW to site peak load.

The revenue generated by each site is largely based on the demand charge from the applicable utility rate schedule multiplied by the site-level demand. Table 2 summarizes key values from the revenue calculation (excluding revenue collected through customer charges and volumetric rates, as the magnitude is negligible compared to the demand charges.)

Table 2. Site load characteristics and tariffs used to calculate program costs

	Con Edison	National Grid (western region)
Average vehicles per site in 2045	50	26
Site load diversity	2.5	2.8
Peak load per site in 2045	1.3 MW	1.8 MW
Applicable tariff	SC9 – Rate I	SC-3 – secondary customers
Tariff structure	Average demand charge of $190.83 per month for first 5 kW of demand and $26.77 for each additional kW	Customer charge of $625 per month; delivery charge of $455.20 per month for first 40 kW of demand and $11.38 for each additional kW

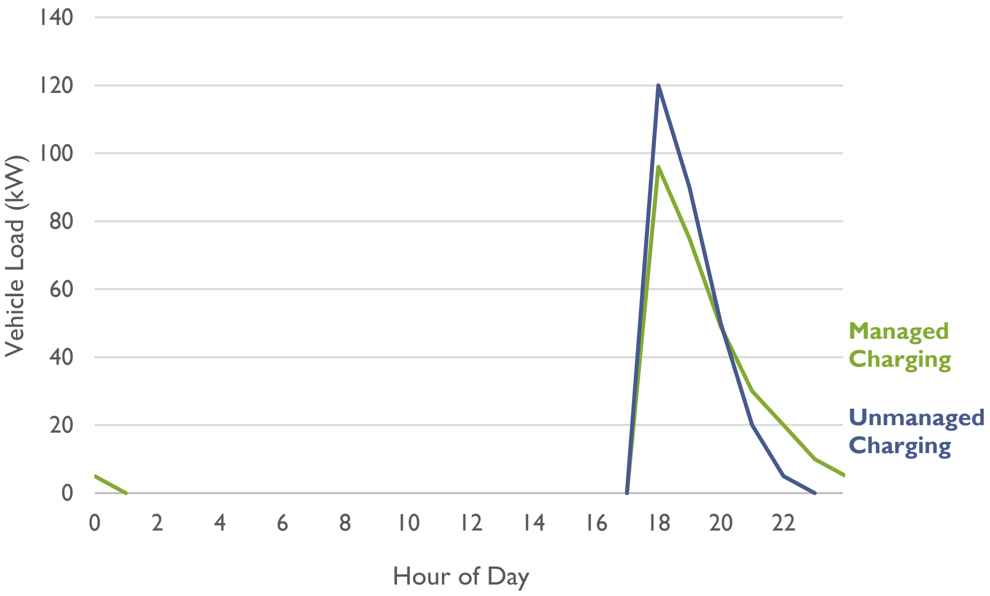
Notes: We defined site load diversity as the ratio of theoretical maximum site demand (if all MHDV chargers operated at full capacity) to the actual coincident peak demand at the site.

2.7. Managed charging

The baseline case described above assumes that vehicle charging is unmanaged, meaning that fleet operators do not adjust the timing of charging to account for grid impacts. Unmanaged charging results in high demand immediately after vehicles are plugged in, and vehicles often finish charging before they are scheduled to go back in service. This creates an opportunity to provide grid benefits by shifting load later during the time period when the vehicle is plugged in, a practice known as managed charging. In the context of distribution system investments, managed charging is particularly valuable for its potential to reduce vehicle peak load.

We developed a sensitivity case to examine the effect of managed charging, reducing each vehicle's rate of charge and spreading it out over two additional hours. This reduces each vehicle's peak demand by 20 percent (Figure 11). While this is a conservative representation of managed charging, it ensures that vehicle charging time does not extend into the time vehicles are expected to be on-duty, as could occur with longer extensions of charging time. For example, data from Con Edison shows that city buses leave their depots at 4:00 AM and do not return until 9:00 PM. This leaves a relatively narrow window of seven hours for the vehicles to charge. Other types of vehicles (e.g., school buses and refuse trucks) have more limited hours of operation and will therefore have greater flexibility to adjust their charging time to flatten their load. We determined that two extra hours of charging was reasonable for an average MHDV in each utility territory, but this analysis could be augmented in the future as data on the demand from MHDV fleets under managed charging becomes more widely available. We also assume in this analysis that vehicles charge at depots, with minimal enroute charging.

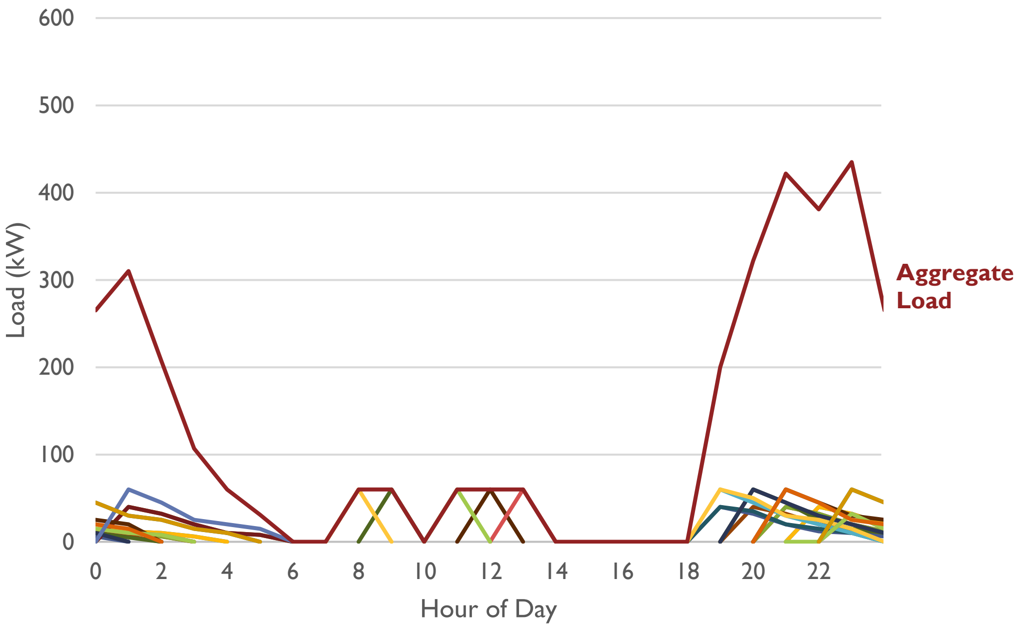
Figure 11. Effect of managed charging on a sample vehicle load curve



Notes: Managed charging reduces the vehicle peak load and extends the charging time.

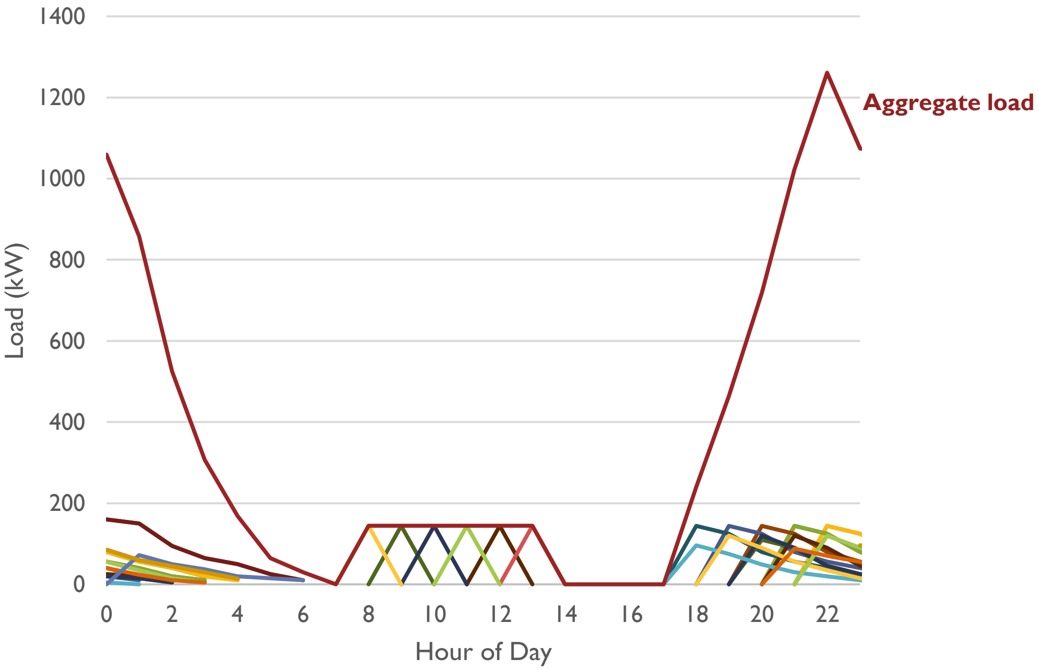
Although the peak demand from each individual vehicle declines by 20 percent, the aggregate impact at the site level is lower (Figure 12 and Figure 13). Site peak load decreases by 15 percent in Con Edison's service area (Figure 14) and by 5 percent in National Grid's service area (Figure 15). We assumed that these scaling factors apply to sites of all sizes in all years. The decrease in site peak load is less than the decrease in individual vehicle peak load because the times when vehicles within a fleet charge are slightly staggered, and because we adjusted the load of each vehicle manually rather than optimizing based on site peak load. The constraints of vehicle operating schedules and the physical characteristics of chargers—primarily that vehicles charge more slowly at higher states of charge—limit the ability of managed charging to decrease site load, although some fleets may find that they are able to achieve greater reductions in peak load through optimization.

Figure 12. Site load diversity under managed charging for a typical site in Con Edison's service area



Notes: Figure shows both the load from individual vehicles and the aggregate load from all 20 vehicles.

Figure 13. Site load diversity under managed charging for a typical site in National Grid's service area



Notes: Figure shows both the load from individual vehicles and the aggregate load from all 20 vehicles.

Figure 14. Effect of managed charging on a sample site in Con Edison's service area with 20 vehicles

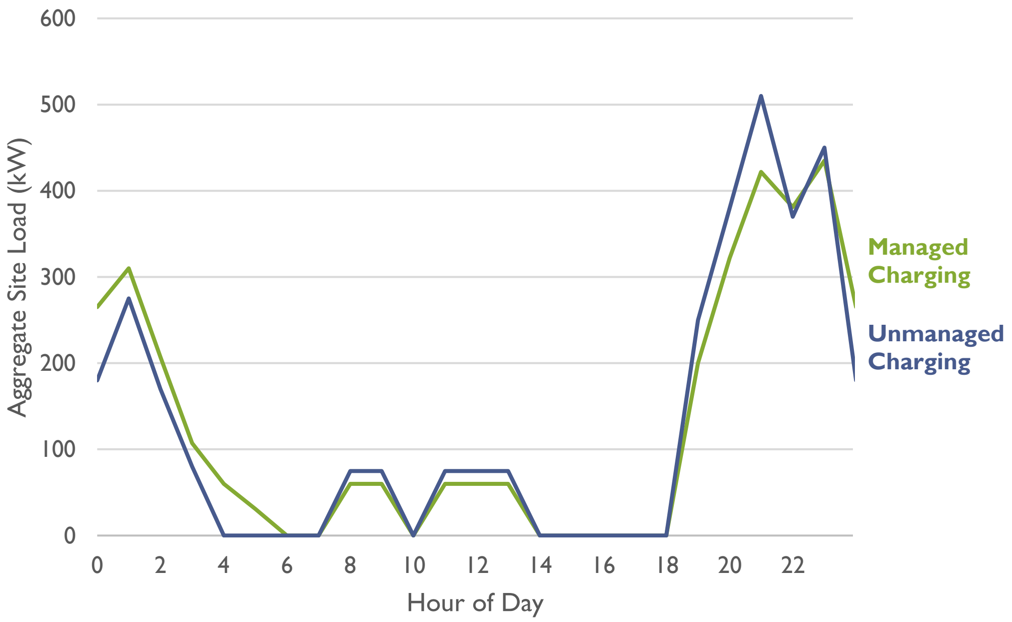
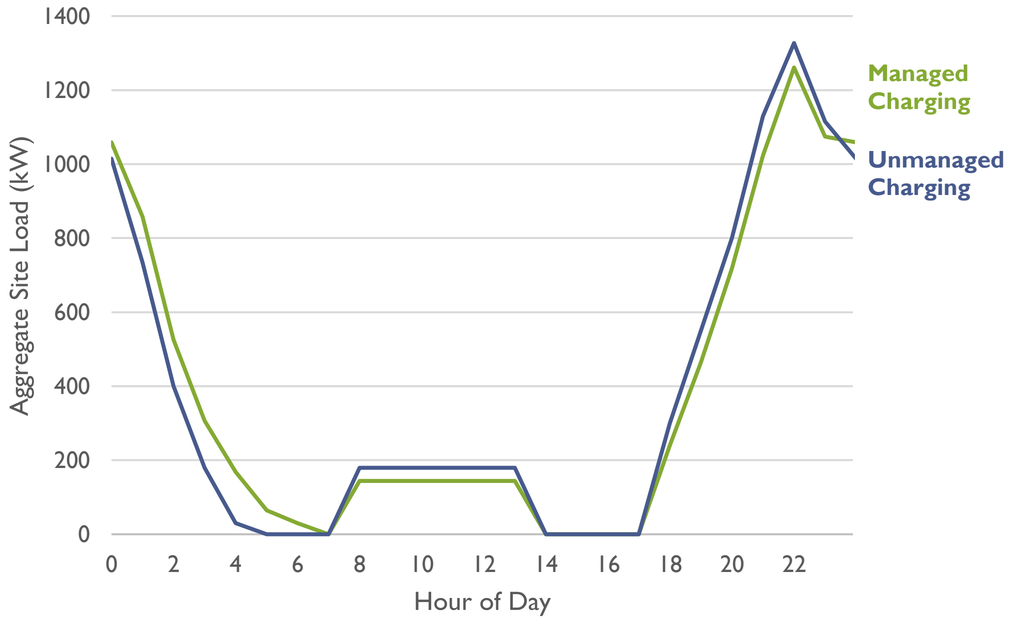


Figure 15. Effect of managed charging on a sample site in National Grid's service area with 20 vehicles



We used a similar technique to determine whether managed charging would impact incremental system costs, first shifting the individual vehicle loads from Figure 7 and Figure 8 so that the unmanaged charging curve matched the vehicle-weighted average of the curves in Figure 5 and Figure 6 as closely as possible, and then adjusting the vehicle loads as before to represent managed charging. The decrease in peak load due to managed charging was indistinguishable from the general noise in the calculation, indicating that managed charging (as we represented it) will not impact the high-level incremental system costs. This is due to the fact that the load curves used at the substation and feeder levels already represent highly diversified loads.

Finally, we used these load impacts to adjust the cost and revenue calculations. We reduced make-ready costs in each year by 20 percent, since these costs scale directly with vehicle peak load in our analytical framework. We recalculated revenue using 15 percent lower site peak load in Con Edison's territory and 5 percent lower site peak load in National Grid's territory. We left incremental system costs unchanged.

3. RESULTS

3.1. Net revenue with unmanaged charging

We find that MHDV electrification generates net positive revenue for Con Edison and has a neutral effect on net revenue in the western region of National Grid's territory (Table 3). We calculate net revenue as a net present value (NPV) using both a 3 percent discount rate, which reflects public interest and intergenerational goals, and a 7 percent discount rate, which approximates the utilities' weighted average cost of capital. With a 3 percent discount rate, the NPV of Con Edison's cumulative net revenue is approximately $820 million from 2023–2045 (Figure 16). For National Grid, cumulative net revenue is close to zero ($320,000) over the same time period (Figure 17). Note that the magnitude of the net revenue for National Grid is only 0.03 percent of the size of total expenditures under the program, meaning that the net revenue impact of the program is essentially neutral. Using a 7 percent discount rate, the NPV of cumulative net revenue under unmanaged charging is $460 million for Con Edison and $1.4 million for National Grid (Appendix A).

Several factors contribute to these results. National Grid has fewer electric vehicles, but they are larger on average, primarily because there are more tractor trailers in upstate New York. This means that National Grid has larger total daily load from electric MHDVs and requires more total charger capacity. The prevalence of sites with low load diversity in National Grid also increases incremental system costs. On the other hand, construction is more expensive in metro New York, so per-kilowatt costs for incremental system upgrades and make-ready infrastructure are higher in Con Edison's territory than National Grid's. Con Edison has higher demand charges, leading to higher revenue to balance the construction costs.

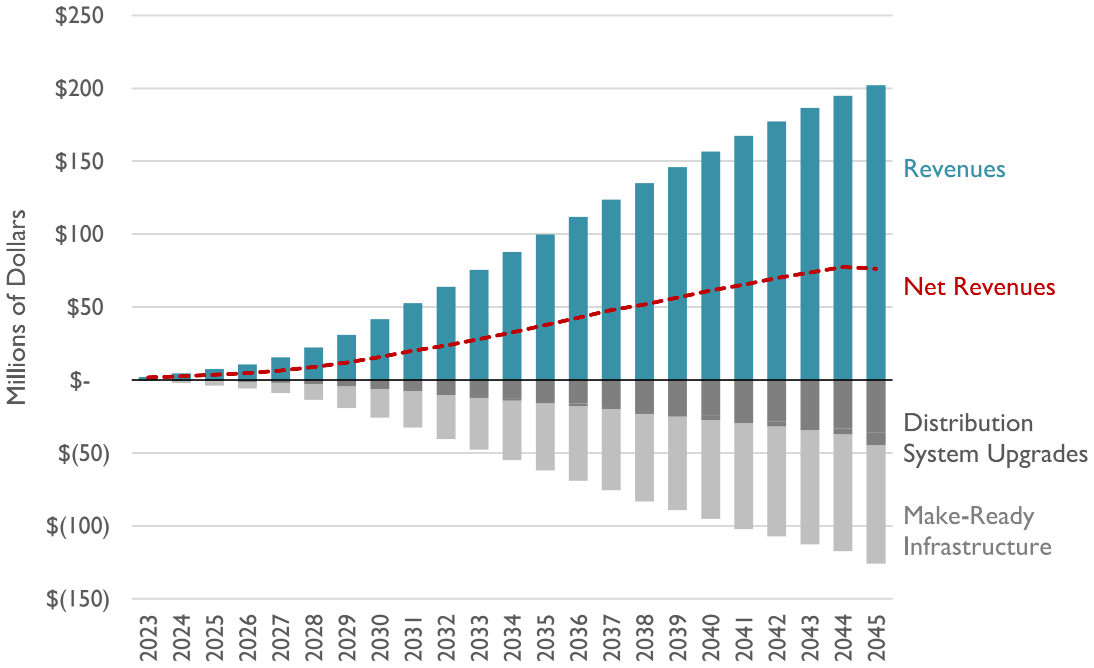
Because many of these factors point in opposite directions, it is not intuitively obvious what the ratepayer impact of either make-ready program will be. Notably, this analysis shows that neither utility service area is likely to experience negative net revenue, despite their very different characteristics. This suggests that MHDV make-ready programs will generally have a neutral to positive impact on ratepayers, with new revenue generated by the programs balancing or outweighing the cost of distribution system upgrades, even if charging is unmanaged.

Table 3. Net present value of cumulative program costs and revenues 2023–2045 with unmanaged charging

	Con Edison		National Grid (western region)	
	3% Discount Rate	**7% Discount Rate**	**3% Discount Rate**	**7% Discount Rate**
Cumulative make-ready costs	($930 million)	($520 million)	($710 million)	($400 million)
Cumulative distribution system upgrade costs	($370 million)	($200 million)	($450 million)	($250 million)
Cumulative revenue	$2.1 billion	$1.2 billion	$1.2 billion	$650 million
Cumulative net revenue	**$820 million**	**$460 million**	**$320 thousand**	**$1.4 million**

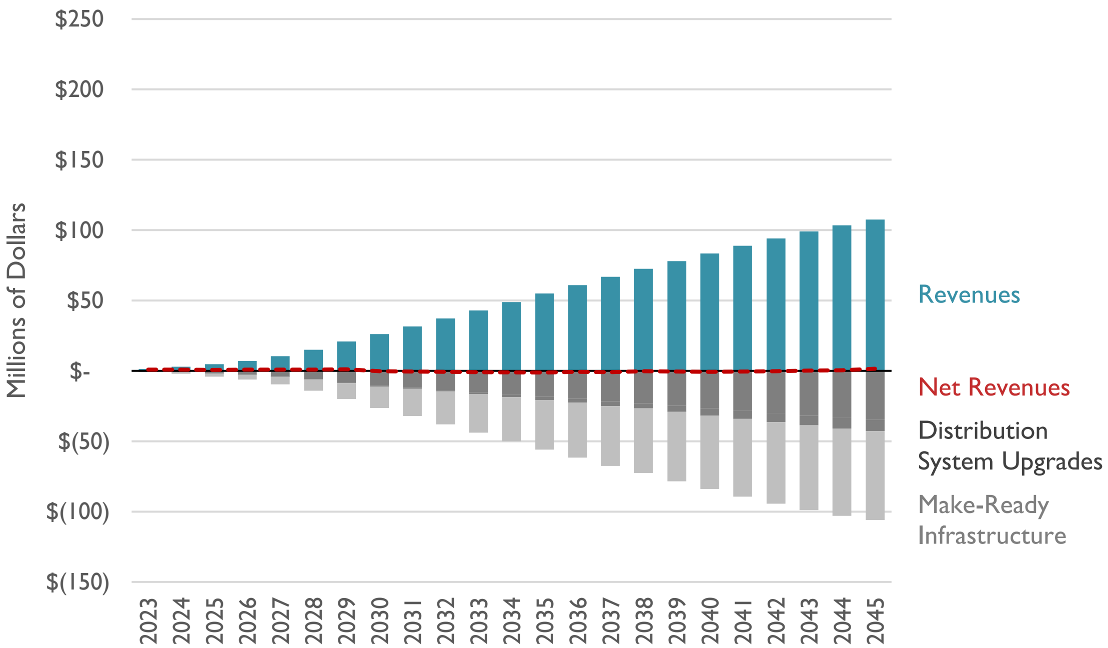
Notes: Numbers do not sum exactly due to rounding.

Figure 16. Cost and revenue impact of a MHDV make-ready program in Con Edison's service area with unmanaged charging



Notes: The program generates net positive revenue in all years. All values shown using a 3 percent discount rate.

Figure 17. Cost and revenue impact of a MHDV make-ready program in the western part of National Grid's service area with unmanaged charging



Notes: The program has a neutral net revenue effect in all years. All values shown using a 3 percent discount rate.

3.2. Net revenue with managed charging

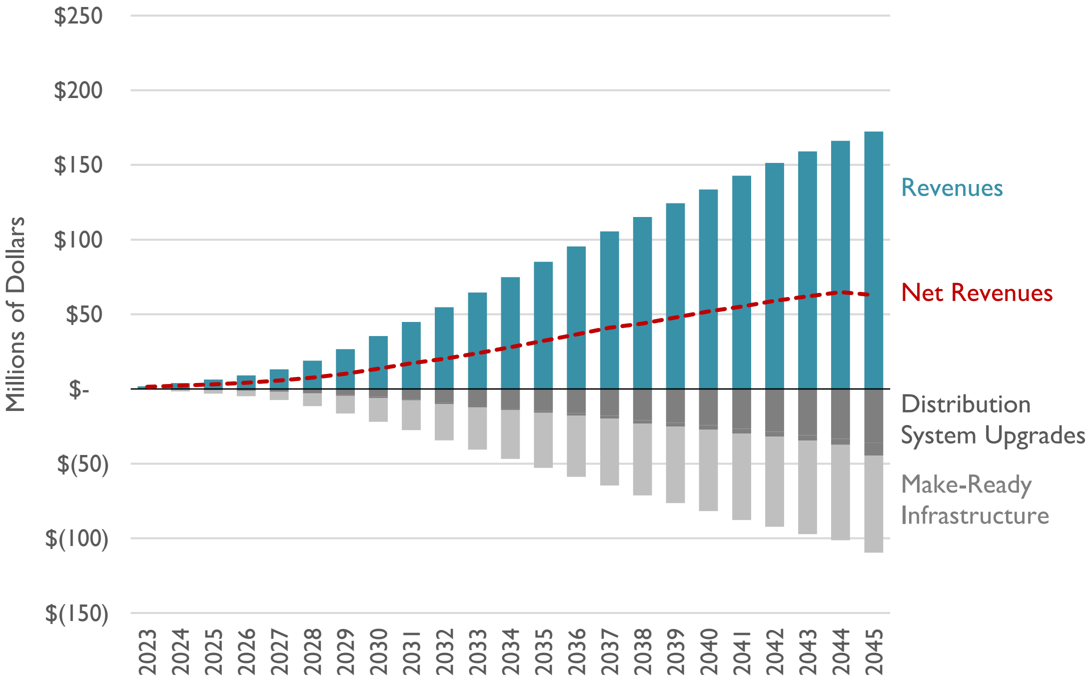
Managed charging reduces make-ready costs by 20 percent and slightly decreases revenue by lowering site peak load. The overall effect on net revenue depends on the balance of these two effects (Table 4). For Con Edison, the NPV of cumulative net revenue with managed charging is $690 million from 2023–2045 using a 3 percent discount rate, which is 15 percent lower than under unmanaged charging, but still positive (Figure 18). For National Grid, the NPV of cumulative net revenue rises to $89 million with managed charging and a 3 percent discount rate (Figure 19). With a 7 percent discount rate, the NPV with managed charging is $390 million for Con Edison and $51 million for National Grid (Appendix A). Even for utilities such as Con Edison where managed charging decreases net revenue, it makes electrification more cost-effective for fleet owners by decreasing the demand charges they must pay. For example, under our representation of managed charging, a typical 50-vehicle site in Con Edison's service area will have a peak demand of 1.3 MW under unmanaged charging and 1.1 MW under managed charging. The decrease in peak site load from managed charging saves fleet owners $61,000 per year in demand charges, a reduction of 15 percent.

Table 4. Cumulative program costs and revenues 2023–2045 with managed charging

	Con Edison		National Grid (western region)	
	3% Discount Rate	**7% Discount Rate**	**3% Discount Rate**	**7% Discount Rate**
Cumulative make-ready costs	($740 million)	($420 million)	($570 million)	($320 million)
Cumulative distribution system upgrade costs	($370 million)	($200 million)	($450 million)	($250 million)
Cumulative revenue	$1.8 billion	$1.0 billion	$1.1 billion	$620 million
Cumulative net revenue	**$690 million**	**$390 million**	**$89 million**	**$51 million**

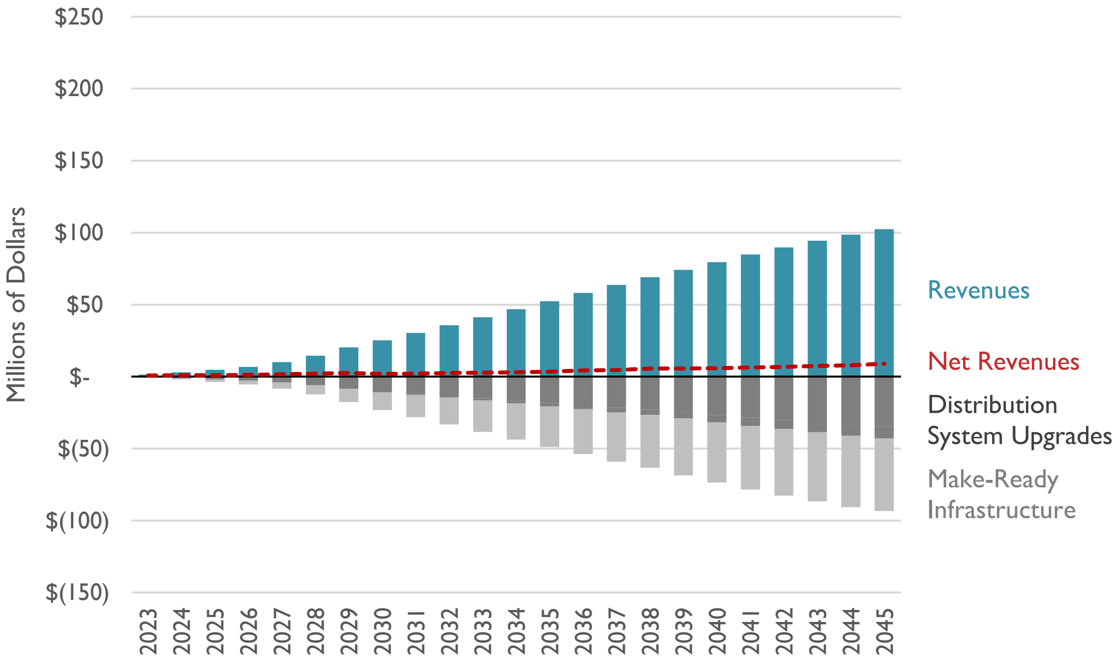
Notes: Numbers do not sum exactly due to rounding.

Figure 18. Effect of managed charging on make-ready program costs and revenue in Con Edison's service area



Notes: Managed charging decreases make-ready costs by 20 percent and also decreases revenue slightly. Net revenue remains positive in all years. All values shown using a 3 percent discount rate.

Figure 19. Effect of managed charging on make-ready program costs and revenue in the western part of National Grid's service area



Notes: Managed charging decreases make-ready costs by 20 percent and also decreases revenue slightly. Net revenue becomes slightly positive in all years. All values shown using a 3 percent discount rate.

3.3. Areas for further research

MHDV electrification is still in its early stages compared to other sectors such as light-duty vehicles. There a number of ways this analysis could be refined and updated in the future as more data becomes available.

- **MHDV load curves:** We applied the highly aggregated load curves for each vehicle type to each substation and feeder to estimate peak demand impacts on the distribution system. To the extent that these load curves overstate load diversity at the substation or feeder level, the system impacts and costs will be understated. Likewise, we did not have site-level load curve data, and thus we estimated these load curves from the aggregate data by reducing the load diversity. To the extent that these site-level load curves overstate load diversity, the local distribution system and site-level costs will be understated, as will revenues.
- **Non-MHDV load projections**: Developing load projections that extend for over two decades is difficult given the sweeping changes in the electricity sector that will occur as other sectors, particularly building space heating and light-duty transportation, electrify. For example, modeling in the *New York Climate Action Council Scoping Plan* suggests

that the electric grid in New York will shift to winter peaking by 2035.[20] More detailed load projections that take into account these changes and that allow for isolation of MHDV load only would improve the accuracy of the analysis.

- **Location of MHDV charging**: We assumed that electric vehicles will charge in the same locations that internal combustion engine vehicles are currently located. As MHDV electrification proceeds in New York, more empirical data will be available about whether this is a valid assumption. Targeted outreach to fleets to determine the locations of future charging would also enable more accurate assessments of grid and make-ready needs. In addition, data from National Grid on the current locations of MHDVs would eliminate some simplifications from the analysis.
- **Make-ready costs:** Make-ready costs vary substantially between projects, but due to limited data availability, this analysis uses a single average make-ready cost per vehicle in each utility service area. As MHDV electrification occurs, there will be more data on actual make-ready costs, as well as the number and size of chargers required by each type of fleet. This will allow for more disaggregated analysis of make-ready costs.
- **Impacts of managed charging:** The potential for managed charging varies by location. Depending on the type of business, fleet owners will have more or less flexibility to shift load. For example, vehicles with longer dwell times and vehicles whose schedule allows them to charge during off-peak hours will have more ability to adjust. A future analysis could capture a finer level of detail by taking these factors into account.

4. CONCLUSIONS

This analysis finds that a make-ready program for MHDV electrification would have a positive to neutral impact on electricity rates in both Con Edison's territory and the western region of National Grid's territory in New York. With unmanaged charging and a 3 percent discount rate, Con Edison's program generates net revenue with an NPV of $820 million from 2023–2045, potentially reducing costs for all ratepayers. In National Grid's territory, unmanaged charging results in close to zero net revenue ($320,000) during the same period. Under a managed charging scenario that decreases each vehicle's peak load by 20 percent, the NPV of cumulative net revenue totals $690 million for Con Edison and $89 million for the western part of National Grid. The NPV of cumulative net revenue is also positive for Con Edison and National Grid under both unmanaged and managed charging using a higher discount rate of 7 percent.

Depending on the utility, managed charging may either increase or decrease net revenue, because it reduces both the cost of necessary infrastructure investments and the program revenue. In either case,

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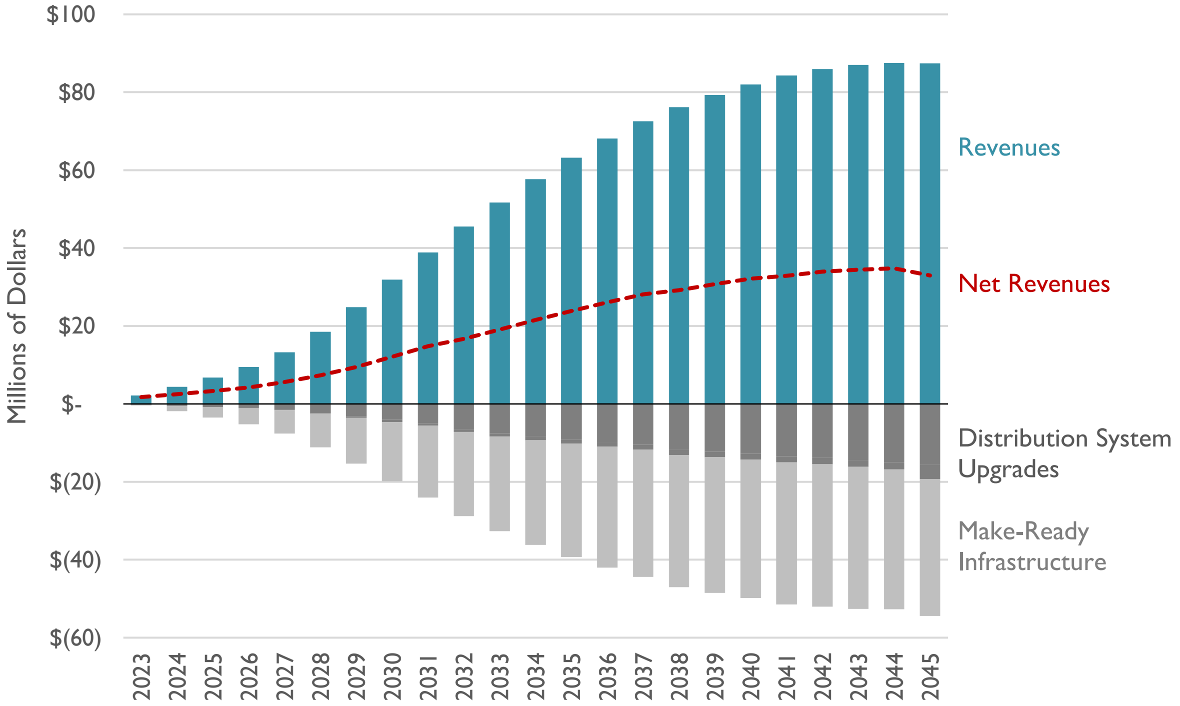
[20] New York Climate Action Council. 2022. *Scoping Plan*. Page 123. Available at: https://climate.ny.gov/-/media/project/climate/files/NYS-Climate-Action-Council-Final-Scoping-Plan-2022.pdf.

managed charging is a valuable technique for reducing program costs and should be a required component of make-ready programs. Managed charging also benefits broader electrification efforts: high demand charges represent another potential barrier to fleet electrification, and managed charging decreases the demand charges that fleet owners must pay. Con Edison and National Grid serve two very different service areas, yet both see positive net revenue with managed charging. This indicates that rate-basing the make-ready and distribution system upgrade costs necessary to meet New York State's MDHV electrification targets will not cause ratepayer bills to increase in either region of the state.

Appendix A. RESULTS WITH 7 PERCENT DISCOUNT RATE

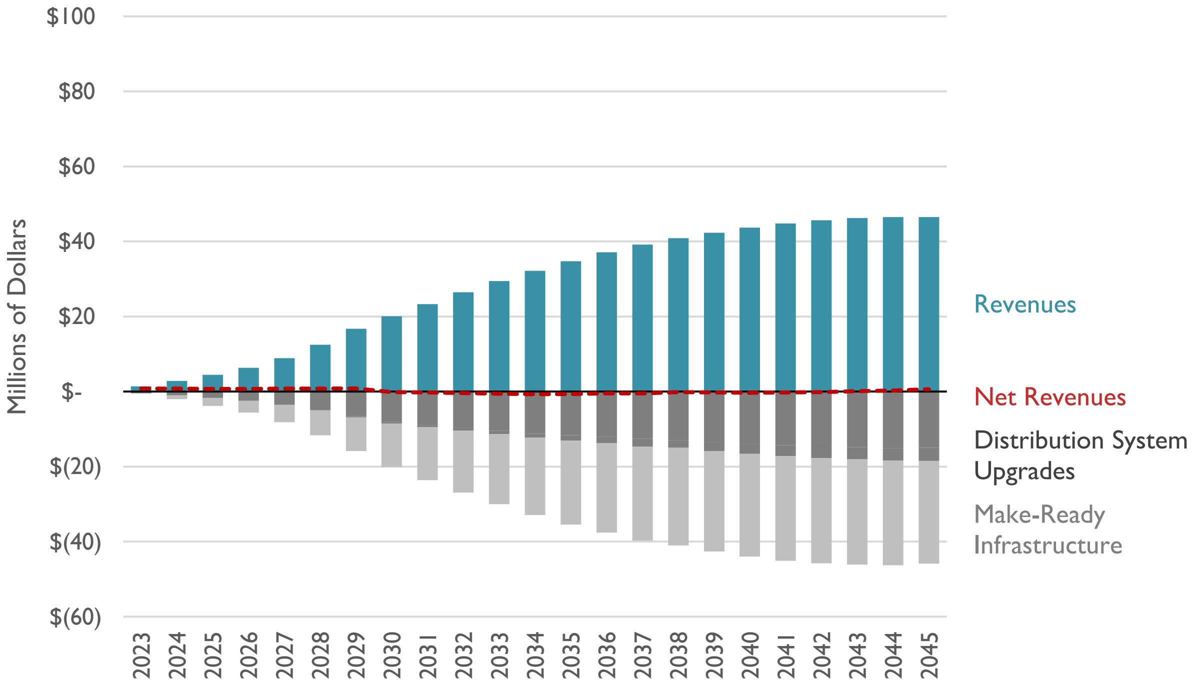
This appendix presents detailed cost and revenue results for Con Edison and National Grid using a 7 percent discount rate. Figure 20 and Figure 21 show results for unmanaged charging, and Figure 22 and Figure 23 show managed charging.

Figure 20. Cost and revenue impact of a MHDV make-ready program in Con Edison's service area with unmanaged charging



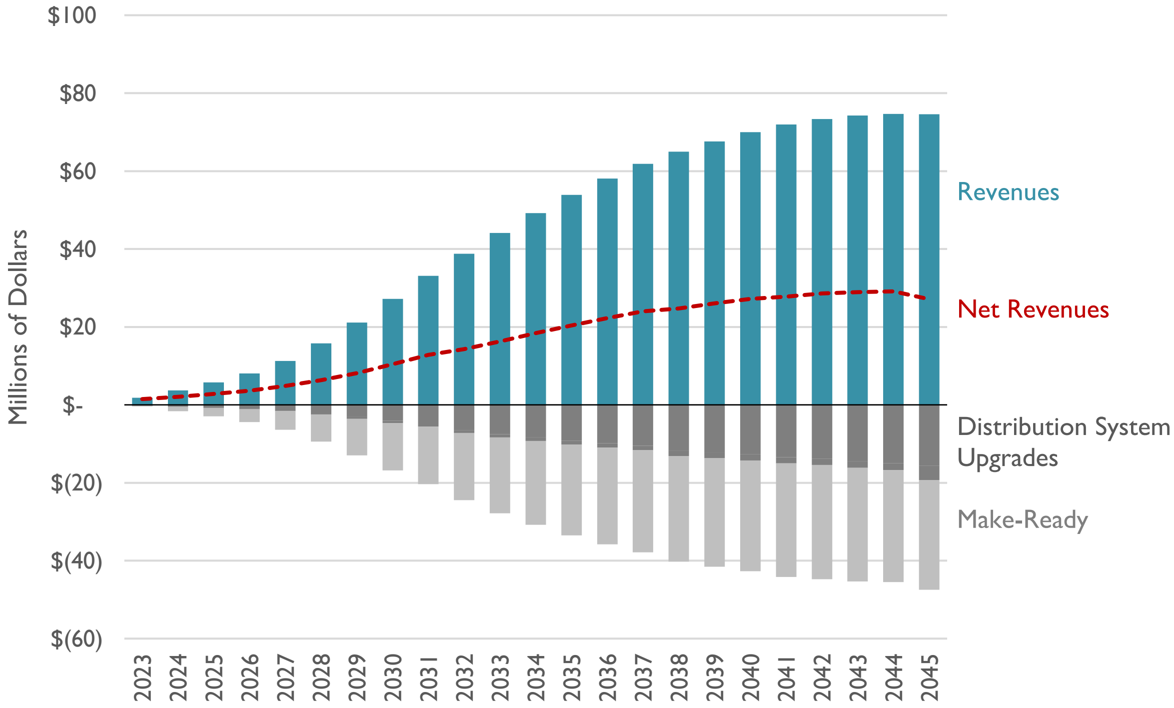
Notes: The program generates net positive revenue in all years. All values shown using a 7 percent discount rate.

Figure 21. Cost and revenue impact of a MHDV make-ready program in the western part of National Grid's service area with unmanaged charging



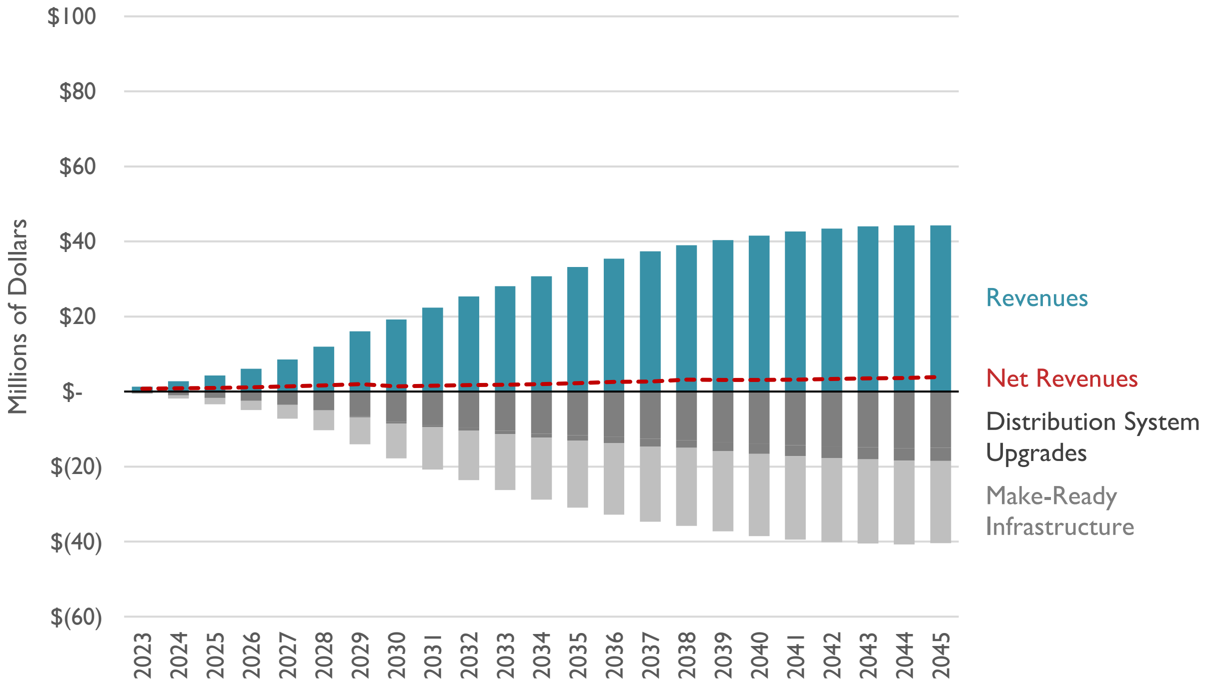
Notes: The program has a neutral net revenue effect in all years. All values shown using a 7 percent discount rate.

Figure 22. Effect of managed charging on make-ready program costs and revenue in Con Edison's service area



Notes: Net revenue remains positive in all years. All values shown using a 7 percent discount rate.

Figure 23. Effect of managed charging on make-ready program costs and revenue in the western part of National Grid's service area



Notes: All values shown using a 7 percent discount rate.