Hixon Final Report

Transboundary Commuting Emissions and their Implications on the Mobility Mitigation Targets of New York City

Daivie Ghosh **Narasimha D. Rao**

Introduction

With increasing decarbonization in the country and region, transboundary travel considerations can matter especially due to the increasing need to integrate electric vehicles (EVs) into not just transit planning but also future grid capacity and demand models. Considering the integration of jobs, economies, and travel in the New York City (NYC) metropolitan region, understanding the effects of transboundary travel emissions needs validation to ensure harmony between the reality of on-ground emissions and the targets outline to mitigate and reduce them.

The project takes the relatively newer targets set in the Electrifying New York report to study if the proposed EV infrastructure will suffice. To do we first test and validate the 50% trip distance emissions accounting method the city uses for its GHG inventory - based on which climate action goals are usually set (Pasion et al., 2017). It also highlights transboundary travel behavior that policymakers or officials might wish to consider in mobility planning because of the nature of EV technology. We also incorporate the increasing importance of workplace charging as highlighted in studies and explores workplace charging in the context of an urban area, where urban form might dictate the use of public chargers as workplace chargers (M. Nicholas et al., 2019; Smart & Salisbury, 2015).

The paper is divided as follows: the rest of the introduction section covers the research questions identified based on project motivations and provides a brief background into climate action planning based on emissions inventories, transboundary travel in the region, and the importance of workplace charging in an increasingly electric future. The methodology section covers the two different analyses covered for transboundary emissions calculations followed by EV charger demand for transboundary commuters. The results and discussions section then focuses on the main findings and how the findings tie into broader regional urban planning and considerations.

Research Questions

Based on the project motivation and research merit, the following research questions were studied:

1) How do the transboundary commuting emissions in the NY Metro region differ based on accounting style?

2) Do NYC's transboundary emissions and in-commuters impact its transportation climate action targets?

GHG Inventories, Scopes, and Climate Action Plans

A baseline greenhouse gas (GHG) inventory (and any subsequent ones) forms the basis of most climate action plan targets (Fong et al., 2014). It forms the crux of establishing GHG emissions mitigation objectives to then set achievable targets over time (Fong et al., 2014). Ensuring the robustness of this data forms a critical step in climate action planning. At the local planning level, cities use their local GHG inventories to set sector-wise similarly for context-specific targets (Pasion et al., 2017). GHG inventories use different "scopes" to calculate GHG emissions to categorize the sector and direct relational nature to the entity emitting the emissions - often divided into Scopes 1 - 3 (Fong et al., 2014). The complications regarding data collection for transboundary emissions remain emphasized in official GHG inventory guidelines and can be included or excluded depending on a local government's capacity (Fong et al., 2014).

What does transboundary commuting in the NYC region look like?

In 2019, ~1 million of NYC's 4.8 million workers commuted in from outside the city (*NYC Metro Region Explorer About*, n.d.). 38% of these 1 million workers commuted by car but the numbers varied depending on where the in-commuters worked (*The Ins and Outs of NYC Commuting*, 2019). To present a broader view of car commuting, ~1.2 million workers (including NYC residents and in-commuters) drove their cars to work with in-commuters making up almost 30% (*The Ins and Outs of NYC Commuting*, 2019). These workers came from 26 counties surrounding NYC that roughly make up the NYC metropolitan area (*NYC Metro Region Explorer About*, n.d.). However, while the region - NYC especially is known for its subways and transit system, at least 38% of these commuters, hereafter referred to as in-commuters, commuted by car (*The Ins and Outs of NYC Commuting*, 2019). Figure 1 (taken from *The Ins and Outs of NYC Commuting*, 2019) below further shows that the workplace location of those who need to drive is, for many commuters, located in the non-Manhattan boroughs somewhat out of reach from the city's subway lines.

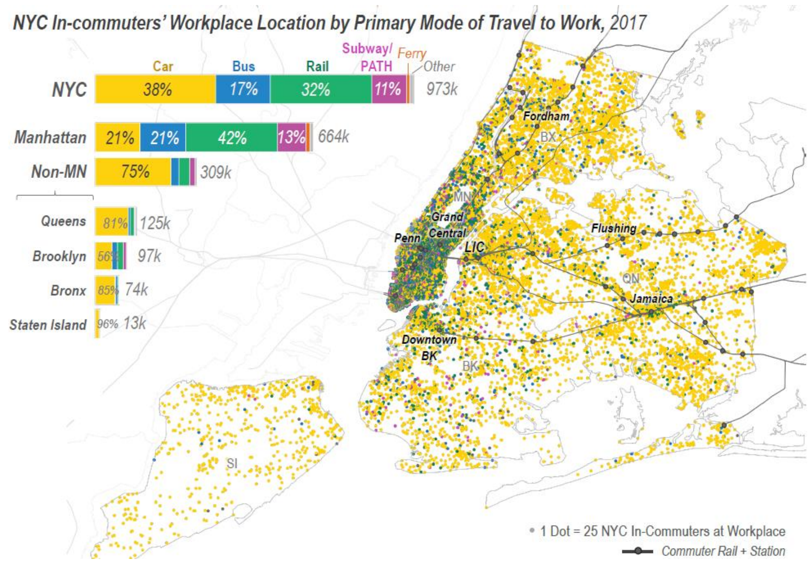

Figure 1: Work location by travel mode for in-commuters (The Ins and Outs of NYC Commuting, 2019)

While Figure 1 reveals key travel behavior of in-commuters in the region, it also brings up questions regarding who is responsible for the environmental and emission impacts for this subsection of the population - and in the context of climate action plans, who accounts for them because they are not NYC residents. We know that NYC has an ambitious target of reducing 80% of its emissions by 2050 (Fuleihan et al., 2019b) and so given the heavy transboundary nature of jobs here, it is necessary to validate the city’s 50% trip distance account method for transboundary travel (Pasion et al., 2017).

Transboundary emissions can get complex because although they are accounted for through scope 3 emissions, on-road transportation emissions attributed to a city might go under-reported in an urban-suburban region (Markolf et al., 2018). Studies in the past have also found that local governments can underreport their emissions by 50% on average (Markolf et al., 2018). The same is especially important at the boundaries or highly contrasting urban and suburban areas with dense urban cores (Markolf et al., 2018).

Workplace Charging

An increasing number of studies have looked at the role that workplace charging could play as people increasingly adopt EVs. One’s workplace or commute location serves as the second most important charging - after the home (Hardman et al., 2018). However, not many studies look at the number of charging locations or spots needed to support market scale diffusion of EVs (Hardman et al., 2018).

In a dynamic region like NYC where at least one million people commuted in (inclusive of all travel modes) pre-COVID for work, considerations for workplace charging could do well to include the working population's needs. This has an impact on both because given the expected decarbonization of most things in the future, the above-identified in-commuters who once drove their gas cars to work might replace them with their electric counterparts. With 30-40% of EV owners expected to use workplace charging daily (Hardman et al., 2018), authorities also need to manage EV charging behavior. As norms and etiquettes around EV workplace charging are still new (Smart & Salisbury, 2015), charging congestion and grid risks remain if all EV drivers plan to plug in and charge their cars in an unmanaged fashion upon arrival (Hardman et al., 2018; Lee et al., 2020).

Electrify NYC Report

In September 2021, NYC released the report: Electrifying New York: An Electric Vehicle Vision Plan for New York City (2021) with new climate targets focusing on electric vehicles and zero emissions technology to reduce emissions - connected to the city's broader OneNYC climate action plan. Given the regional interdependence and planning for the NYC metro area and the importance of workplace charging identified above it remains critical to assess the strength of the relatively new EV goals.

Methods

The calculations and analyses for the project were split into two parts. Part 1 calculated the transboundary commuting emissions for in-commuters to NYC. Part 2 relates transboundary emissions to NYC's climate action plan targets by calculating the number of chargers needed to support weekday in-commuters demand.

Dataset: Weekday travel data was obtained from the Local Area Transportation Characteristics for Households (LATCH survey). The survey is a synthetic dataset developed by the Bureau of Transportation Statistics that used regression to combine the National Household Travel Survey (NHTS) and the American Community Survey (ACS) from the Census departments to get weekday travel data. The dataset has four main variables as the outcome, from which the variable “Average weekday household vehicle-miles traveled by U.S. Census tract (per day)” was used.

All data cleaning, wrangling, and analyses were done in R for both parts.

Part 1 calculations: The CSV file from the LATCH survey was downloaded from the above-mentioned variable. The LATCH survey provided data at the census tract level, and data were extracted for all census tracts for the 26 counties in the New York City metropolitan area (excluding NYC). These included the following counties listed on NYC’s metro region planning website and used in the regional commuting document cited in Figure 1 (*NYC Metro Region Explorer About*, n.d.; *The Ins and Outs of NYC Commuting*, 2019):

- *New Jersey*: Bergen, Essex, Hudson, Middlesex, Morris, Passaic, Somerset, Union, Hunterdon, Mercer, Monmouth, Ocean, Sussex, and Warren
- *New York*: Nassau, Suffolk, Putnam, Rockland, Westchester, Dutchess, Orange, Sullivan, and Ulster
- *Connecticut*: Fairfield, Litchfield, and New Haven

The GEOIDs were cleaned from their original state FIPs code, and a state variable was added based on the GEOIDs. Because the variable of interest, provided total weekday travel VMT, the value was adjusted for work-related VMT only based on regional commute information for Long Island, Mid-Hudson, Connecticut, New Jersey (except Mercer), and Mercer counties from an older regional travel survey (*2010/2011 Regional Household Travel Survey (RHTS)*, 2014). In-commuter travel data provided in *The Ins and Outs of NYC Commuting*, (2019) was broken down based on the number of workers in the region, the percentage of workers who worked in NYC, and how many of the workers drove their cars to work and scaled up to the county level. This was further split at the Manhattan and Non-Manhattan levels to obtain the number of in-commuters who drove to Manhattan and Non-Manhattan boroughs (Brooklyn, Bronx, Queens, and Staten Island). Table 1 provides this information.

Table 1: Number of In-commuters driving to Manhattan and non-Manhattan boroughs

County	State	city_car_mh	city_car_nmh
New Haven	Connecticut	385	471
Fairfield	Connecticut	4743	5809
Litchfield	Connecticut	385	471
Sullivan	New York	88	132
Westchester	New York	24421	39902
Orange	New York	5586	8341
Ulster	New York	88	132
Nassau	New York	25310	88950
Putnam	New York	1475	2410
Dutchess	New York	265	395
Bronx	New York	NA	NA
Rockland	New York	4098	6695
Richmond	New York	NA	NA
Queens	New York	NA	NA
Kings	New York	NA	NA
Suffolk	New York	9688	34048
New York	New York	NA	NA
Bergen	New Jersey	13382	9005
Essex	New Jersey	7528	5065
Hunterdon	New Jersey	174	176
Mercer	New Jersey	1570	1588
Monmouth	New Jersey	5758	5824
Ocean	New Jersey	872	882
Somerset	New Jersey	1533	1032
Morris	New Jersey	2370	1595
Sussex	New Jersey	349	353
Union	New Jersey	3903	2626
Hudson	New Jersey	15892	10693
Middlesex	New Jersey	5715	3846
Warren	New Jersey	174	176
Passaic	New Jersey	1673	1126

GHG Emissions

After calculating the number of in-commuters and where they were driving to in NYC, the GHG emissions were calculated for 1) total trip work trip distance 2) 50% of the transboundary trip distance (as accounted for according to NYC's GHG Inventory Report (Pasion et al., 2017)), and 3) portion of the trip only occurring within NYC's boundaries.

ArcGIS online was used to calculate the portion of the trip occurring within NYC based on county centroids. The county centroid method was used based on methodologies from other studies that have also used county centroids to calculate travel emissions (Caponio et al., 2015; Frank et al., 2011). This was used to deduce the portion of the trip occurring within NYC and outside NYC - which was applied to the commuting VMT. Different vehicle mileages were used for parts of the trips occurring within and outside NYC based on information provided by Challa et al (2022). This was done because for internal combustion engine vehicles, highway fuel mileage is much higher than for city driving - which is more inefficient (Challa et al., 2022).

After adjusting for vehicle fuel mileage, the CO_2e (carbon dioxide equivalent) emissions were calculated for each of the three mentioned methods above. The CO_2e calculations included emissions of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) as per emissions calculations guidance provided by the US EPA (EPA, 2020).

Part 2 calculations: To assess the impact of transboundary commuter travel on NYC's climate action plan goal for EV chargers, the number of chargers needed to satisfy one-way trip charging demand was calculated for in-commuters. EV charging occurs at different frequencies at the home versus workplace/public locations given the associated differences in cost (M. A. Nicholas & Tal, 2015). The charger demand was calculated for 2030 and 2050 for three different scenarios by estimating the charging consumption based on assumptions about differences in the cost to charge. First, the EV charging consumption (in MWh) was calculated based on factors such as one-way commuting distance and EV charging efficiency (Element Energy Limited, 2016) as shown in Figure 2.

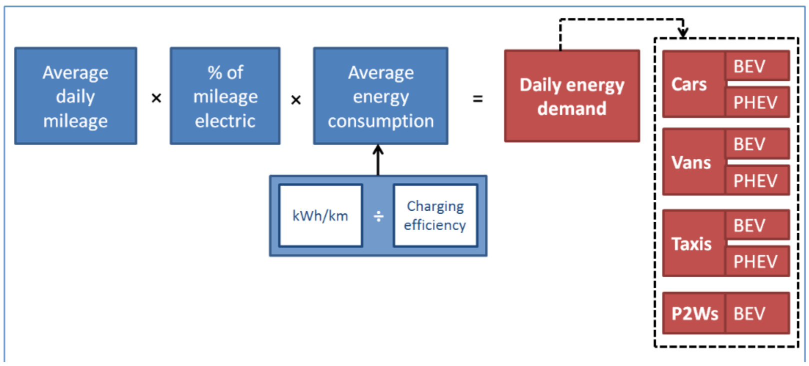

Figure 2: Formula for EV consumption (Element Energy Ltd. 2016)

Scenarios: Charger demand was calculated for a combination of 2030 and 2050, and projected the demand for a baseline, paid, and free EV charging scenario. The paid scenario assumed that the cost of electricity at the workplace was twice that of home and no money was charged for the free scenario (M. A. Nicholas & Tal, 2015). This varied the percentage of commuters who charged their cars at work depending on cost. Increasing EV diffusion in the vehicle fleet was considered for the 2030 and 2050 scenarios - i.e., for the light-duty vehicle stock (Fox-Penner et al., 2018; Weiss et al., 2019).

For the charger demand, a general methodology provided by (M. Nicholas et al., 2019) was used also shown in Figure 3. Given the type of public EV charging infrastructure that NYC plans to install, charger demand was calculated for L-2 (level 2 chargers) (*Electrifying New York: An Electric Vehicle Vision Plan for New York City*, 2021). Doing so required electricity consumption for the in-commuters, calculating the charging time based on consumption and charger rate, calculating the daily electricity demand per charger, and scaling that up to the total electricity consumption demand. As with the emissions calculations, this was calculated for Manhattan and non-Manhattan areas separately.

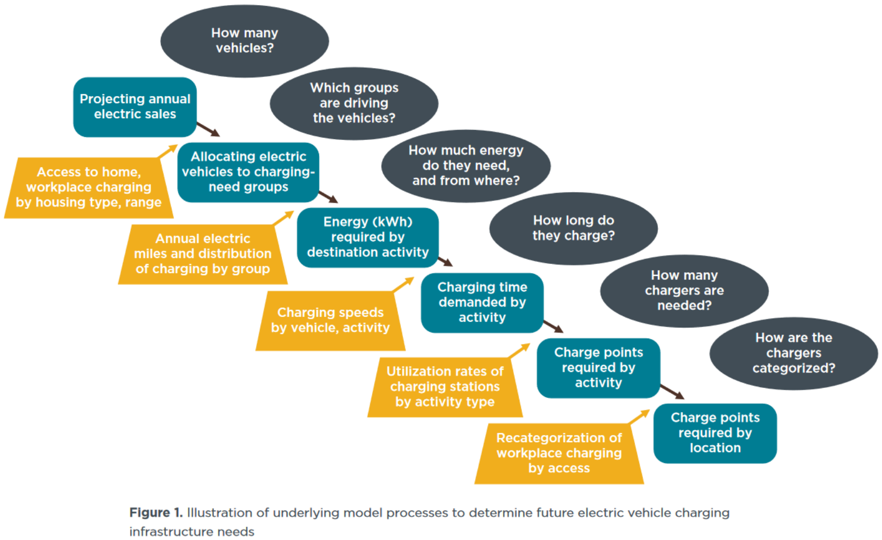

Figure 3: Line of logic for calculating chargers needed for in-commuters (Nicholas et al., 2019)

Table 2 shows variables used to calculate charging electricity consumption and resulting charger demand to satisfy the MWh demand.

Table 2: Variables used for calculating electricity consumption and resulting charger demand

Variable Name	**Variable**	**Source**
EV Efficiency (kWh/mile)	0.34	(Harris & Webber, 2014)
Charging Efficiency	0.85	(D. Wu et al., 2019)
2030 EV% of LDV Stock	17%	(Fox-Penner et al., 2018; Weiss et al., 2019)
2050 EV% of LDV Stock	72%	(Fox-Penner et al., 2018; Weiss et al., 2019)
% EV commuters using workplace charging daily	30%	(Smart & Salisbury, 2015)
Cost scenarios: % EV commuters using workplace charging daily (free and paid)	80% and 20%	(M. A. Nicholas & Tal, 2015)
L2 Charger Rate	6.6 kW	(*Summary Report on EVs at Scale and the U.S. Electric Power System*, 2019; X. Wu, 2018)
Workplace dwell time	6 hours	(Li et al., 2020)

Results

Part 1: In-commuting Emissions

The calculations for Part 1 revealed that the transboundary commuting emissions for the in-commuters calculated for portion of the trip occurring within NYC were close to the emissions calculated using NYC's 50% VMT assumption. The total annual emissions for in-commuters driving to NYC were 500,420 tonnes of CO_2e and 534,590 tonnes of CO_2e respectively for using 50% of the trip distance versus using only the portion of the trip that occurs inside NYC.

The total transboundary emissions calculations above largely agreed with NYC's 50% calculation. We then compared the results for the two accounting methods spatially to see if there were any important GHG emissions differences between the counties. Figures 4 and 5 below show a map of each county's contribution to the city's GHG emissions via in-commuters. The maps do not show much of a difference for most of the counties between the two GHG accounting methodologies (shown in light yellow). The counties of Westchester, Suffolk, and Nassau stand out as the highest contributors to the city's in-commuting emissions. However, Figure 5 for the portion of the trip occurring only within NYC shows a large difference in annual emissions for Nassau County in-commuters of ~100,000 tonnes CO_2e.

The results show that NYC appears to under-account GHG emissions for in-commuters by only ~6% revealing that the 50% trip distance that NYC uses to account for all transboundary trips is an appropriate methodology given data complexity. Nevertheless, Nassau's specific situation reveals that the total number of in-commuters, as well as the percentage of workers who might be driving to non-Manhattan boroughs, plays an important role in contributing to the emissions.

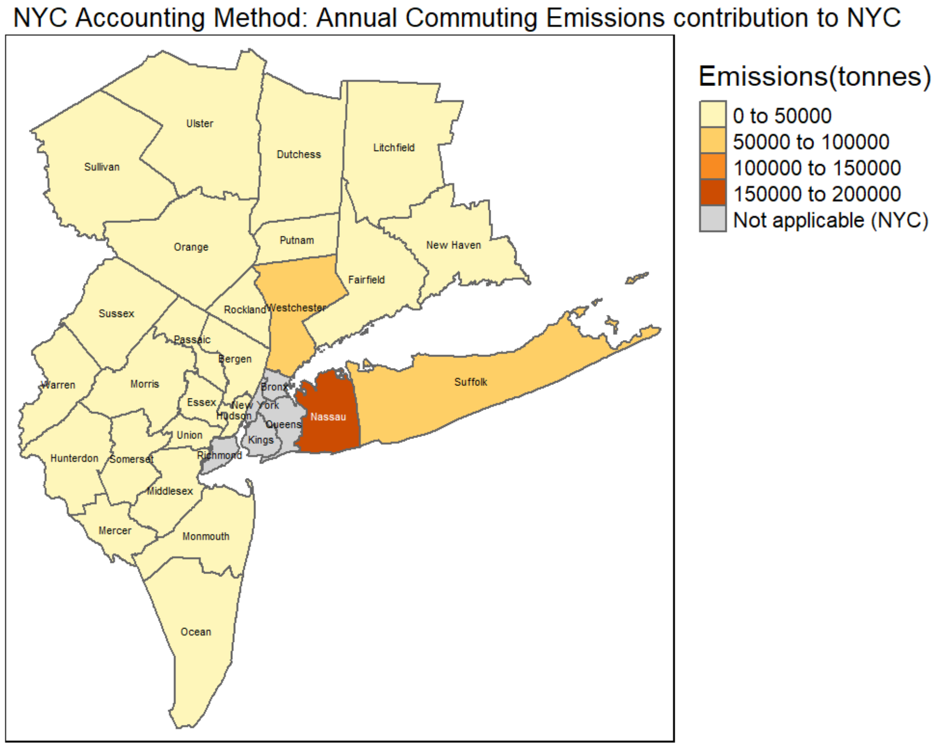

Figure 4: Annual Commuting Emissions to NYC (50% VMT)

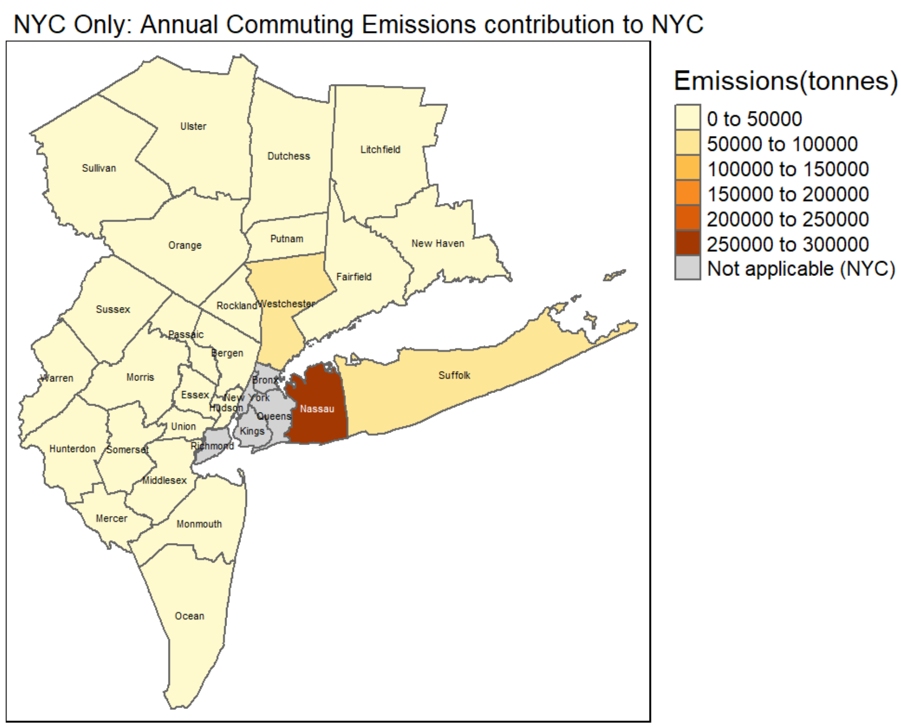

Figure 5: Annual Commuting Emissions to NYC (Portion of the trip within NYC only)

Validating the above was helpful because it reveals that in the case of lacking data, using 50% of a trip distance is reasonable. Thus, this allowed us to proceed with the knowledge that the basis of the climate action plan targets to reduce emissions (usually set based on GHG inventory values) was robust.

Part 2: Validating NYC's Climate Action Plan targets in the context of in-commuters

Given that the city's GHG inventory might be accounting for most of the in-commuting emissions (as seen in Part 1 above), Part 2 of the results looks at how in-commuters fit into the remainder of NYC's transit-related climate action planning.

To understand the extent to which in-commuters might potentially dominate or overtake EV chargers being planned for and built out in NYC, the number of chargers required to charge for a one-way trip back home daily was calculated for a few different scenarios. Figure 6 below shows that charger demand for in-commuters in NYC is lowest when it is paid and increases drastically for the free scenario. The charger demand for 2050 is much higher than for 2030 because 2050 assumes a greater diffusion of EVs in the vehicle fleet.

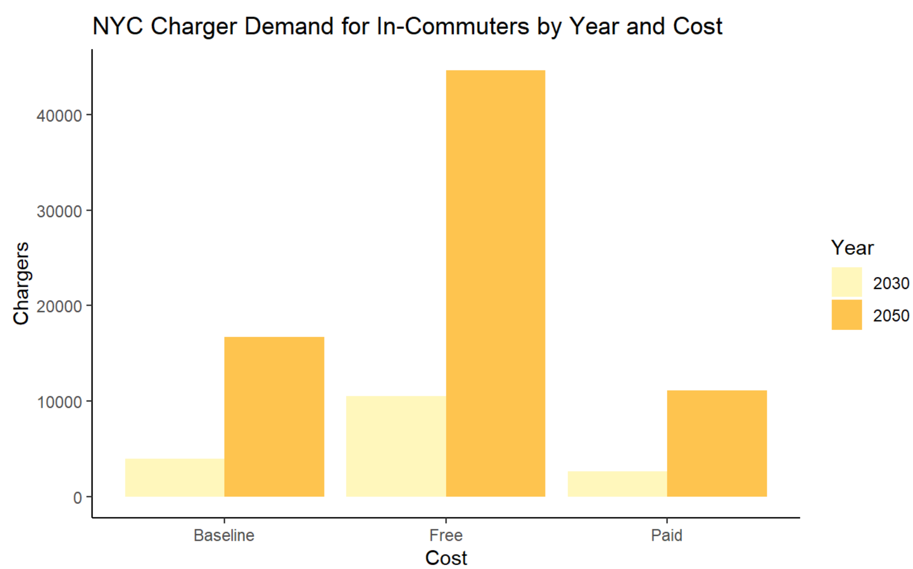

Figure 6: In-commuter charger demand projections

Table 3 provides a further breakdown of the charger demand by location in NYC for in-commuters. We see that overall, there appears to be greater in-commuter charger demand for non-Manhattan boroughs. The free charging scenario dominates charger demand regardless of work destination. NYC's Electrifying New York report provides details on the number of EV chargers the city plans to install by 2030 and 2050 (*Electrifying New York: An Electric Vehicle Vision Plan for New York City*, 2021). We then compared what percent of the city's planned chargers would potentially be used by in-commuters during the day based on results from Figure 4.

The column, PctNYC_ChargerUse, in Table 3 shows that the percentage of roughly stays the same across 2030 to 2050 charger installations in NYC that sees an increase of public L2 chargers from 40,000 to 160,000. Table 3 shows that even in the paid scenario, where fewer people charge their EVs, 7% of the city's EV charging infrastructure could be used up by in-commuters. The free scenario shows that almost a quarter (26-28%) of the city's public L2 chargers from 2030 to 2050 could be occupied by in-commuters on a given weekday. The baseline scenario still sees around 1/10 of the city's chargers being occupied by in-commuters regardless of year. The results show that depending on the pricing level of a public charger in NYC, between 7-26% and 7-28% of the chargers might be overtaken by in-commuters. This hints at the fact that depending on how chargers are priced in the future, current EV charging goals might be an underestimation of what is needed for NYC's demand - when including in-commuters who might spend most of their day at work in the city. The implications for the same are discussed in the next section.

Table 3: Charger demand by NYC location for in-commuters

Cost	Year	Manhattan_Chargers	Nonmanhattan_Chargers	NYC_Chargers	PctNYC_ChargerUse
Baseline	2030	1447	2504	40000	10
Free	2030	3862	6670	40000	26
Paid	2030	963	1668	40000	7
Baseline	2050	6129	10597	160000	10
Free	2050	16353	28262	160000	28
Paid	2050	4087	7065	160000	7

Discussion

EV chargers needed: Part 2 of the results that show the extent to which in-commuters could potentially use reveals the importance of pricing structures for increasing levels of EV diffusion. This is important because the 40,000 and 160,000 chargers that NYC hopes to install by 2030 and 2050 have been planned for in accordance with a certain number of EVs in NYC that city residents are projected to own. The number of chargers planned for installation by NYC appears to have been calculated at a 10:1 ratio for chargers to EVs which is set to be an optimal ratio used by researchers and research institutes alike (Fuels Institute, 2022; Talluri et al., 2019). This brings up the issue of in-commuters possibly free-loading off of EV charging infrastructure developed using NYC tax money for public use - with city resident's not being able to utilize the chargers to the full extent and causing inconvenience.

It is also possible that the time of usage for EV chargers for these in-commuters may not coincide with the expected usage timings for NYC residents. The usage period for which the charger demand was calculated is the workday. It is most likely possible that an NYC resident might choose to charge their own EVs at night (in the case of street parking) and there might not be too many chances of charger congestion or conflicts during the daytime hours.

Pricing matters because the cost structure can impact EV charging demand. Free workplace charging has been mostly acceptable given the somewhat nascency of EV diffusion. Studies show that increasing levels of EV usage means that offering free workplace charging cannot be a sustainable economic model in the long term (M. A. Nicholas & Tal, 2015). The results above also corroborate the same to an extent.

Currently, the NYC government websites reveal pricing structures for public chargers in the city including for chargers being installed and for any future ones (cite). While it is given that NYC would most likely not provide free public charging to recoup investments and prevent charger congestion, unknowns remain regarding the split and use of public chargers as workplace chargers versus offices providing dedicated workplace charging. The above results for in-commuters potentially occupying 26-28% of chargers are based on the assumption of the electricity rate is double that of the home. Policymakers and government officials thus also have to consider commercial public charging rates compared to what one might pay at home when setting prices.

Charger congestion and climate action plans: An unintended consequence of charger congestion could be that it dissuades people from buying EVs and holding on to their gas cars for a while longer. If NYC residents, for whom the chargers were originally intended, notice potential charger congestion when they might hold off on purchasing EVs due to the perceived lack of charging infrastructure. Other than NYC residents being unable to benefit from the chargers, it might also bring up issues of NYC not being able to achieve its target EV levels. The impact could cascade into other aspects of the climate action plan such as not achieving the target levels of total transportation GHG emissions reduction of 70% by 2050 (Fuleihan et al., 2019b). On the other hand, in-commuters driving to the city from further out might face a similar problem considering range anxiety.

The three states in the metropolitan area (New York, New Jersey, and Connecticut) have similar but different EV rollout and sales targets ranging from 2030 to 2040 (Alternative Fuels Data Center, n.d.-a, n.d.-c, n.d.-b). The situation leads to the risk of in-commuters also continuing the use of older gas cars and contributing to emissions within NYC, especially as the city works to eliminate its transportation emissions. The situation could be critical for instances where in-commuters need to drive their cars in due to a lack of alternate transit options. The latest 2022 climate action plan progress report by NYC lists the status of EV charging spots as "reconsidered" for enacting legislation "requiring 40% of new parking spots to be "EV ready" and 20% of spots to contain EV charger" (Charles-Guzman, 2022). Uncertainty on this front presents further cause for concern given knowledge of the EV charger demand.

Policy implications: This brings into question the issue that although it is not NYC's responsibility to plan and account for the travel behavior for EV infrastructure, the city coordinates and plans for regional travel through other existing agencies and has been doing so for years. A search into climate action planning or even emissions accounting for the villages, towns, and cities in the 26 metro region counties revealed that most have not considered such planning yet (Appendix 1).

Due to the nature of gas cars, there has not been a similar issue plaguing cross-regional authorities until now. As the future of transportation shifts to cleaner modes, authorities might need to grapple with the realities of how to smoothly coordinate travel for newer technologies where the needs differ from that of the incumbents. Authorities and policymakers will also need to grapple with finding a balance while trying to promote an overall mode shift from cars to public transit that requires addressing other highlighted issues.

The above results and discussion also assume simply replacing a gas car with its electric, zero-emissions counterpart. To decarbonize transportation, there is also a need to reduce single occupancy vehicle reliance, i.e., shift to different transit modes while simultaneously reducing the number of gas cars in the vehicle fleet. Thus, considerations for reducing the number of in-commuters to NYC can contribute to both the EV charging congestion issue, reduce regional GHG emissions and improve air quality. NYC is in the process of starting a congestion pricing scheme for its Central Business District to reduce congestion in Manhattan (Ley, 2022). But the scheme only targets Manhattan. Figure 1 shows that most of the in-commuters drive to the other four boroughs, highlighting that the congestion pricing would not address congestion in these areas (*The Ins and Outs of NYC Commuting*, 2019).

Non-Manhattan driving accounts for most of the charger demand as well calling into question where the charger demands are being located (not stated in the climate action plan reports). Also, worth looking into are the reasons why so many workers drive their cars to these locations. The lack of public transit lines for the origin and/or destination could be one of the main reasons. It thus bears further investigation for how one might want to shift this population to a different travel mode and investigate steps and policies to realize them. The city's own climate action plan calls for increasing sustainable mode shares to 80% of all trips by 2050 (Fuleihan et al., 2019a) - leaving room for consideration here regarding how to - or whether policymakers let the in-commuters be a part of the remaining 20%.

Limitations

The above results had a few limitations due to the nature of the data. The trip VMT data was from a synthetic dataset and contained VMT averages for the entire county. Given the long trip distances for some of the in-commuters from counties farthest away, county VMT averages might not have been reflected too well in the LATCH dataset. The project did not use real trip data either and so there might be other variations in actual VMT. The calculations only considered VMT for work and did not account for changes in demand through trip chaining that might be more reflective of real-world behavior. EV charging demand studies in the past have looked at both, trip chaining and only one-way work trip demands which is why given the lack of trip chaining data, we proceeded with assuming work commute VMT only (Li et al., 2020; X. Wu, 2018).

This project only considered battery electric vehicles and did not consider the presence and usage of battery hybrid or plug-in hybrid electric vehicles. Future projections by government agencies such as the EIA show slightly increasing rates of hybrid vehicles in the markets (EIA, 2022). However, by 2050 their market presence is a small fraction compared to BEVs which is why they were not considered for this study. It is worth noting that BEVs do not appear to overtake plug-in hybrids until the mid-2030s and so an added sensitivity for plug-in hybrids until around 2030 could be of importance.

Although there was data on the number of commuters driving to Manhattan and non-Manhattan boroughs, a further breakdown was not available. As a result, the borough-level breakdown of where EV chargers are needed was not calculated. Having access to this data by being able to look at EV charger needs for the remaining four boroughs would help pinpoint the exact location of potential EV charger conflict. Furthermore, NYC's Electrifying New York report does not detail how the city plans to allocate chargers by boroughs either (*Electrifying New York: An Electric Vehicle Vision Plan for New York City*, 2021). Having information regarding how the city plans to do so and being able to compare it to borough-specific charger demand by in-commuters would be further essential for city policymakers.

The project also had a few smaller limitations regarding EV functionality. Miles gained back from regenerative braking were not considered which might be worth considering in the future since EVs are more efficient in cities (Challa et al., 2022). State of charge considerations to preserve battery and battery efficiency losses in winter were not considered either which could impact electricity usage (Faria et al., 2019; D. Wu et al., 2019).

Conclusion

To summarize the findings, we found that in the absence of real-world data for the portion of a trip occurring within NYC's political boundaries, using the 50% trip VMT method to account for emissions for transboundary commuters (as NYC does) was reasonable. This validated the basis for NYC's GHG inventory allowing further analysis of the climate action plans. The final analysis of the city's planned EV chargers as per its climate action plan found that depending on how EV charging is priced, between 7-26% and 7-28% of the EV chargers could potentially be overtaken by in-commuters in 2030 and 2050 respectively. The findings call attention to the role of pricing especially as EVs reach higher market diffusion rates.

Finally, from a climate action planning perspective for NYC to achieve its transportation targets, there remain a few factors to be considered for in-commuters - for which certain solutions or backups necessitate further investigation. Unless charging costs are considered holistically, there remains potential for in-commuters to overtake some of NYC's planned L2 EV charger spots. The transboundary nature of the issue complicates the issue because scope 3 emissions of in-commuters for NYC are scope 1 emissions for the location where the commuters reside. But given the scale of transit regional planning that occurs around New York City, coordinating the same at a larger scale through statewide authorities is worth considering.

References

2010/2011 Regional Household Travel Survey (RHTS). (2014). New York Metropolitan Transportation Council and North Jersey Transportation Planning Authority. https://www.nymtc.org/portals/0/pdf/RHTS/RHTS_FinalReport%2010.6.2014.pdf

Alternative Fuels Data Center. (n.d.-a). *Connecticut Laws and Incentives*. Retrieved December 15, 2022, from https://afdc.energy.gov/laws/all?state=CT

Alternative Fuels Data Center. (n.d.-b). *New Jersey Laws and Incentives*. Retrieved December 15, 2022, from https://afdc.energy.gov/laws/all?state=NJ

Alternative Fuels Data Center. (n.d.-c). *New York Laws and Incentives*. Alternative Fuels Data Center. Retrieved December 15, 2022, from https://afdc.energy.gov/laws/all?state=NY

Caponio, G., Mascolo, G., Mummolo, G., Mossa, G., & Digiesi, S. (2015). *Commuting carbon dioxide (CO2) emissions: A study of ten Italian metropolitan cities* [XX Summer School “Francesco Turco”]. http://summerschool-aidi.it/edition-2015/images/Naples2015/proceed/32_caponio.pdf

Challa, R., Kamath, D., & Anctil, A. (2022). Well-to-wheel greenhouse gas emissions of electric versus combustion vehicles from 2018 to 2030 in the US. *Journal of Environmental Management*, *308*, 114592. https://doi.org/10.1016/j.jenvman.2022.114592

Charles-Guzman, K. (2022). *OneNYC-2022-Progress-Report.pdf*. https://onenyc.cityofnewyork.us/wp-content/uploads/2022/05/OneNYC-2022-Progress-Report.pdf

EIA. (2022, March 3). *Annual Energy Outlook 2022—U.S. Energy Information Administration (EIA)*. https://www.eia.gov/outlooks/aeo/narrative/consumption/sub-topic-01.php

Electrifying New York: An Electric Vehicle Vision Plan for New York City. (2021). Mayor’s Office of Climate and Sustainability. https://www1.nyc.gov/html/dot/downloads/pdf/electrifying-new-york-report.pdf

Element Energy Limited. (2016). *Plug-in Electric Vehicle Uptake and Infrastructure Impacts Study*. https://content.tfl.gov.uk/ev-uptake-and-infrastructure-impacts-study-updated-nov-2016.pdf

EPA. (2020). *Greenhouse Gas Inventory Guidance: Direct Emissions from Mobile Combustion Source*.

Faria, M., Duarte, G., & Baptista, P. (2019). Assessing electric mobility feasibility based on naturalistic driving data. *Journal of Cleaner Production*, *206*, 646–660. https://doi.org/10.1016/j.jclepro.2018.09.217

Fong, W. K., Sotos, M., Doust, M., Schultz, S., Marques, A., Deng-Beck, C., Kovac, A., Bhatia, P., Russell, B., Morris, E., van Staden, M., Arikan, Y., Eichel, A., Dickinson, J., Desai, R., Hoornweg, D., Harris, N., Carreño, C., Lee, D., … Quinn, R. (2014). *Global Protocol for Community-Scale Greenhouse Gas Inventories: An Accounting and Reporting Standard for Cities Version 1.1* (p. 190). World Resources Institute, C40 Cities and ICLEI. https://ghgprotocol.org/sites/default/files/standards/GPC_Full_MASTER_RW_v7.pdf

Fox-Penner, P., Gorman, W., & Hatch, J. (2018). Long-term U.S transportation electricity use considering the effect of autonomous-vehicles: Estimates & policy observations. *Energy Policy*, *122*, 203–213. https://doi.org/10.1016/j.enpol.2018.07.033

Frank, L. D., Greenwald, M. J., Kavage, S., & Devlin, A. (2011). *An assessment of urban form and pedestrian and transit improvements as an integrated GHG reduction strategy*. (WA-RD 765.1). https://rosap.ntl.bts.gov/view/dot/20279

Fuels Institute. (2022). *EV Charger Deployment Optimization: Summary of Findings*. https://www.fuelsinstitute.org/wp-content/uploads/2022/12/EVC-Micro-Demand.pdf

Fuleihan, D., Williams, D., & Zarrilli, D. A. (2019a). *OneNYC 2050: EFFICIENT MOBILITY* (p. 36). THE CITY OF NEW YORK, MAYOR BILL DE BLASIO. http://onenyc.cityofnewyork.us/strategies/efficient-mobility/

Fuleihan, D., Williams, D., & Zarrilli, D. A. (2019b). *OneNYC 2050: BUILDING A STRONG AND FAIR CITY* (p. 332). CITY OF NEW YORK MAYOR BILL DE BLASIO. https://onenyc.cityofnewyork.us/wp-content/uploads/2020/01/OneNYC-2050-Full-Report-1.3.pdf

Hardman, S., Jenn, A., Tal, G., Axsen, J., Beard, G., Daina, N., Figenbaum, E., Jakobsson, N., Jochem, P., Kinnear, N., Plötz, P., Pontes, J., Refa, N., Sprei, F., Turrentine, T., & Witkamp, B. (2018). A review of consumer preferences of and interactions with electric vehicle charging infrastructure. *Transportation Research Part D: Transport and Environment*, *62*, 508–523. https://doi.org/10.1016/j.trd.2018.04.002

Harris, C. B., & Webber, M. E. (2014). An empirically-validated methodology to simulate electricity demand for electric vehicle charging. *Applied Energy*, *126*, 172–181. https://doi.org/10.1016/j.apenergy.2014.03.078

Lee, J. H., Chakraborty, D., Hardman, S. J., & Tal, G. (2020). Exploring electric vehicle charging patterns: Mixed usage of charging infrastructure. *Transportation Research Part D: Transport and Environment*, *79*, 102249. https://doi.org/10.1016/j.trd.2020.102249

Ley, A. (2022, August 18). Why Drivers Could Soon Pay $23 to Reach Manhattan. *The New York Times*. https://www.nytimes.com/2022/08/18/nyregion/nyc-congestion-pricing-manhattan.html

Li, S., Xie, F., Huang, Y., Lin, Z., & Liu, C. (2020). Optimizing workplace charging facility deployment and smart charging strategies. *Transportation Research Part D: Transport and Environment*, *87*, 102481. https://doi.org/10.1016/j.trd.2020.102481

Markolf, S. A., Matthews, H. S., Azevedo, I. M. L., & Hendrickson, C. (2018). The implications of scope and boundary choice on the establishment and success of metropolitan greenhouse gas reduction targets in the United States. *Environmental Research Letters*, *13*(12), 124015. https://doi.org/10.1088/1748-9326/aaea8c

Nicholas, M. A., & Tal, G. (2015). *Charging for Charging at Work: Increasing the Availability of Charging Through Pricing*. 16. https://itspubs.ucdavis.edu/download_pdf.php?id=1919

Nicholas, M., Dale, H., & Nic, L. (2019). *Quantifying the electric vehicle charging infrastructure gap across U.S. markets* (p. 39). International Council on Clean Transportation. https://theicct.org/wp-content/uploads/2021/06/US_charging_Gap_20190124.pdf

NYC Metro Region Explorer About. (n.d.). NYC Department of City Planning. Retrieved December 8, 2022, from https://metroexplorer.planning.nyc.gov/Commuting/total-nycworkerres

Pasion, C., Oyenuga, C., & Gouin, K. (2017). *City of New York Inventory of New York City's Greenhouse Gas Emissions*. Mayor's Office of Sustainability.

Smart, J. G., & Salisbury, S. D. (2015). *Plugged In: How Americans Charge Their Electric Vehicles*. Idaho National Laboratory. https://avt.inl.gov/sites/default/files/pdf/arra/PluggedInSummaryReport.pdf

Summary Report on EVs at Scale and the U.S. Electric Power System. (2019). Grid Integration Tech Team and Integrated Systems Analysis Tech Team. https://www.energy.gov/sites/prod/files/2019/12/f69/GITT%20ISATT%20EVs%20at%20Scale%20Grid%20Summary%20Report%20FINAL%20Nov2019.pdf

Talluri, G., Grasso, F., & Chiaramonti, D. (2019). Is Deployment of Charging Station the Barrier to Electric Vehicle Fleet Development in EU Urban Areas? An Analytical Assessment Model for Large-Scale Municipality-Level EV Charging Infrastructures. *Applied Sciences*, *9*(21), Article 21. https://doi.org/10.3390/app9214704

The Ins and Outs of NYC Commuting. (2019). [Research Release]. NYC Planning. https://www1.nyc.gov/assets/planning/download/pdf/planning-level/housing-economy/nyc-ins-and-out-of-commuting.pdf

Weiss, J., Hagerty, M., & Castañer, M. (2019). *The Coming Electrification of the North American Economy: Why We Need a Robust Transmission Grid*. The Brattle Group. https://wiresgroup.com/wp-content/uploads/2020/05/2019-03-06-Brattle-Group-The-Coming-Electrification-of-the-NA-Economy.pdf

Wu, D., Guo, F., Field, F. R., De Kleine, R. D., Kim, H. C., Wallington, T. J., & Kirchain, R. E. (2019). Regional Heterogeneity in the Emissions Benefits of Electrified and Lightweighted Light-Duty Vehicles. *Environmental Science & Technology*, *53*(18), 10560–10570. https://doi.org/10.1021/acs.est.9b00648

Wu, X. (2018). Role of workplace charging opportunities on adoption of plug-in electric vehicles – Analysis based on GPS-based longitudinal travel data. *Energy Policy*, *114*, 367–379. https://doi.org/10.1016/j.enpol.2017.12.015

Appendix 1: Climate Action Plans in the NYC Metropolitan Region

County	Town/City/Village	Climate Action Plan link
Bergen County, NJ;	Glen Rock	https://glenrocknj.net/index.asp?SEC=8641F482-5D2E-4A5C-A0EB-9AAD62258A0B&DE=75FF5D89-C039-4DC6-8BAC-E84FBD353355&Type=B_BASIC
Essex County, NJ;	South Orange Village	https://southorange.org/325/Environmental-Commission
Hudson County, NJ;	Hoboken	https://www.hobokennj.gov/resources/greenhouse-gas-emissions-inventory-and-climate-action-plan#:~:text=The%20Hoboken%20Climate%20Action%20Plan,required%20to%20achieve%20those%20goals.&text=Carbon%20neutral%20means%20to%20reduce,inventoried%20sources%20of%20carbon%20emissions.
	Jersey city	http://jcmakeitgreen.org/
	Secaucus	https://secaucusnj.gov/environmental-team.html
Hunterdon County, NJ;		
Middlesex County, NJ	East Brunswick	Commited
	Highland Park	https://sustainablehighlandpark.org/shp-news/
	North Brunswick	http://www.sustainablejersey.com/actions-certification/actions/?type=1336777436&tx_sjcert_action%5BactionObject%5D=26&tx_sjcert_action%5Baction%5D=getPDF&tx_sjcert_action%5Bcontroller%5D=Action&cHash=76e0b9dc3159b578d21ae6b5e9e1a727
	Plainsboro	http://plainsboronj.com/DocumentCenter/View/4432/paris_climate_accord_-resolution?bidId=
Monmouth County, NJ;	Long Branch	Committed
	Marlboro	https://www.marlboro-nj.gov/green/gt-mission.html
Morris County, NJ;	Chatham Township (IP)	https://chathamtownship-nj.gov/vertical/sites/%7B440F80DF-7E94-40B8-B1AE-CE161FC4406A%7D/uploads/CTECminutes_100620v2.pdf
	Mount Arlignton	Land Use Pledge: https://mountarlingtonnj.org/wp-content/uploads/2021/01/Res-2021-27___ENDORSING-SUSTAINABLE-LAND-USE-PLEDGE.pdf REGIONAL COOPERATION mentioned
Ocean County, NJ;		
Passaic County, NJ;		
Somerset County, NJ;		
Sussex County, NJ;		
Union County, NJ;	Fanwood	https://www.fanwoodnj.org/about-fanwood/sustainable-jersey/

	Summit	https://www.cityofsummit.org/DocumentCenter/View/606/Climate-Action-Plan-PDF-?bidId=
	Union City	Committed
Bronx County, NY;		
Kings County, NY;		
Nassau County, NY;		
New York County, NY;	NYC	https://onenyc.cityofnewyork.us/
Putnam County, NY;		
Queens County, NY;		
Richmond County, NY;		
Rockland County, NY;	Nyack	https://nyack-ny.gov/sustainability/
Suffolk County, NY;	County itself	https://www.molloy.edu/Documents/suffolk_final.pdf
Westchester County, NY; and	County itself	https://climatechange.westchestergov.com/images/stories/pdfs/GblWrmAction2008FINAL.pdf
	Ardsley Village	Committed
	Dobbs Ferry Village	https://www.dobbsferry.com/sites/dobbsferryny/files/uploads/df_cap_final_2017-09-26_1.pdf
	Hastings on Hudson	https://www.hastingsgov.org/sites/hastingsonhudsonny/files/uploads/hastingssustainabilityaction_plan.pdf
	Irvington	https://www.irvingtonny.gov/400/Environmental-Action-Plan
	Ossining	http://greenossining.org/docs/GreenOssining_ClimateActionPlan.final.pdf
	White Plains	https://www.cityofwhiteplains.com/628/GO-GREEN-White-Plains
Pike County, PA.		
Sullivan	County	https://sullivanny.us/sites/default/files/departments/sustainableenergy/SC_Climate_Action_Plan_March_24_2014.pdf
	Bethel	https://townofbethelny.us/sustainable-bethel
	Highland	https://townofhighlandny.com/departments/climate-smart-community/
Ulster	County	https://ulstercountyny.gov/sites/default/files/documents/environment/UC%202018%20community%20GHG%20inventory%20report_final.pdf
	Kingston	https://engagekingston.com/climate-action-plan#:~:text=The%20City%20of%20Kingston%20is,over%20the%20next%2010%20years.
	Gardiner	https://static1.squarespace.com/static/5bd1e899da50d36cfc91e963/t/5ea706a61fdccb23b6f5a8d8/1588004524088/Town+of+Gardiner+Climate+Action+Plan+2019+Final.pdf

	Marbletown	https://www.marbletown.net/sites/g/files/vyhlif4666/f/uploads/marbletown_govt_climate_action_plan_2019.pdf
	Saugerties	http://csc-site-persistent-prod.s3.amazonaws.com/fileadmin/cicbase/documents/2019/5/21/15584527290839.pdf
Orange	Resilience plan in progress	https://www.orangecountygov.com/2113/Climate-Resilience-Plan
Duchess	County	In progresshttps://www.dutchessny.gov/Departments/Planning/docs/DutchessCAPI-1-20-CSCTaskForcePresentation.pdf
	Beacon	http://agenda.cityofbeacon.org/AttachmentViewer.ashx?AttachmentID=9900&ItemID=5536
Litchfield		
New Haven		
Fairfield	Fairfield	https://www.fairfieldct.org/filestorage/10736/12858/17526/19132/66116/66118/Sustainability_Plan.pdf
Warren		
Mercer	Hamilton	https://www.hamiltonnj.com/news/?FeedID=93