Decarbonizing New York Through Optimizing Distributed Resources

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1 Study Description

Vibrant Clean Energy (VCE®) was commissioned by Vote Solar, Local Solar for All, and the Coalition for Community Solar Access (CCSA) to study the role of distributed resources in decarbonizing New York's electric sector by 2040 and achieving economy-wide electrification by 2050. The two scenarios discussed in this report model New York undergoing economy-wide electrification with decarbonization of the electricity sector, while comparing outcomes based on differing assumptions for the role of distributed generation. The modeling was performed using the WIS:dom®-P, a state-of-the-art model capable of performing detailed capacity expansion and production cost while co-optimizing utility-scale generation, storage, transmission, and distributed energy resources (DERs). The modeled scenarios use the National Renewable Energy Laboratory (NREL) Annual Technology Baseline (ATB) 2020 "advanced" cost projections for installed capital and Operation and Maintenance (O&M) costs. For fuel costs, forecasts from the Annual Energy Outlook (AEO) 2020 High Oil and Gas supply scenario are used.[1]

The scenarios modeled in this study assume New York must achieve: 70% renewable electricity by 2030; 100% zero-emission electricity by 2040; and economy-wide electrification by 2050. In addition, conventional nuclear generation follows a currently proposed retirement schedule, and the following minimum technology capacity deployments were assumed for renewable capacity and storage: 3 gigawatts (GW) of distributed solar by 2023 and 6 GW by 2025; 3 GW of storage by 2030; and 2.4 GW of offshored wind by 2030 and 9 GW by 2035.Aside from those assumptions, each scenario was modeled as follows:

(1) **Electrify and decarbonize NY while limiting distributed generation (DG) deployment and without distribution co-optimization ("Constrained & Non-Optimized DER"):** In this scenario, New York undergoes economy-wide electrification and decarbonization of the electricity sector *without* co-optimizing the distribution system with the utility-scale generation. In addition, the distributed solar deployment (including the combination of onsite distributed photovoltaics (DPV) and community solar power (CSP)) is capped at 6 GW, and distributed storage is *not* an available technology for the model to deploy. This scenario serves as a counterfactual to compare changes in system costs and retail rates for customers as a result of co-optimizing the distribution system and utilizing distributed generation.

(2) **Electrify and decarbonize NY with distribution co-optimization ("Optimized DER"):** In this scenario, WIS:dom-P co-optimizes the distribution system with utility-scale generation in New York while undergoing economy-wide electrification and decarbonization. Distributed solar and distributed storage are allowed to grow as determined by the model.

The scenarios are initialized and calibrated with 2018 generator, generation, and transmission topology datasets. The scenarios then determine a pathway from 2020 through 2050 with results outputted every 5 years. As part of the optimal capacity

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[1] https://www.eia.gov/outlooks/aeo/data/browser/#/?id=3-AEO2020&region=1-0&cases=highogs&start=2018&end=2050&f=A&linechart=highogs-d112619a.3-3-AEO2020.1-0~highogs-d112619a.36-3-AEO2020.1-0~highogs-d112619a.37-3-AEO2020.1-0~highogs-d112619a.38-3-AEO2020.1-0~highogs-d112619a.39-3-AEO2020.1-0~highogs-d112619a.40-3-AEO2020.1-0&map=highogs-d112619a.4-3-AEO2020.1-0&sourcekey=0

expansion, WIS:dom-P must ensure each grid meets reliability constraints through enforcing the planning reserve margins specified by the North American Electric Reliability Corporation (NERC) and having a 7% load following reserve available at all times. Detailed technical documentation describes the mathematics and formulation of the WIS:dom-P software along with input datasets and assumptions.[2]

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[2] https://vibrantcleanenergy.com/wp-content/uploads/2020/08/WISdomP-Model_Description(August2020).pdf

1.1 WIS:dom®-P Model Setup

To investigate the role of distributed generation in decarbonizing New York's electric sector by 2040 and ultimately achieving economy-wide electrification by 2050, WIS:dom-P modeled New York with its existing generator topology, transmission, and weather inputs obtained from National Oceanic and Atmospheric Administration (NOAA) High Resolution Rapid Refresh (HRRR) model[3] at 3-km horizontal resolution and 5-minute time resolution. The initialized generator dataset is created by aligning the Energy Information Administration Form 860 (EIA-860) dataset[4] with the 3-km HRRR model grid. The existing generator topology in New York in 2018 along with existing transmission at 3-km resolution is shown in Figure 1.1. The areas shaded in yellow are provisional locations of disadvantaged communities (DACs) in New York derived from data available through the New York State Energy Research and Development Authority (NYSERDA).[5]

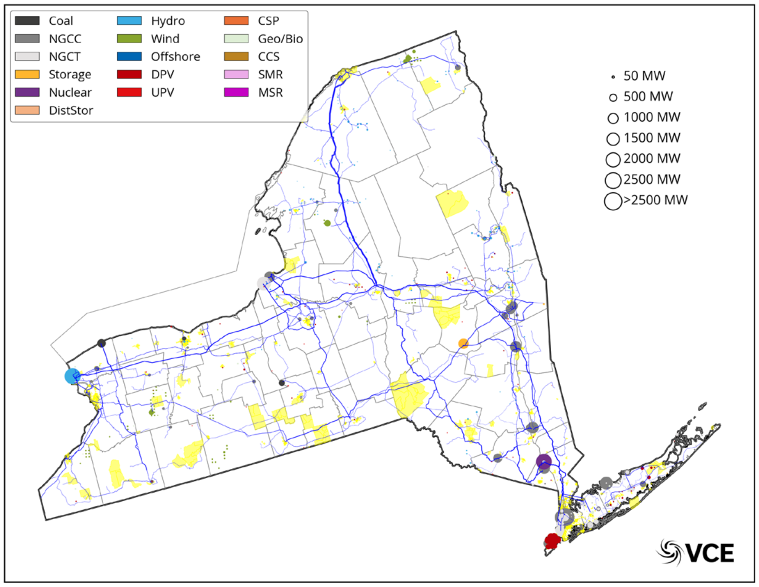

Figure 1.1: WIS:dom-P model domain and existing generators with transmission. The regions shaded yellow are locations of disadvantaged communities.

Existing transmission corridors between New York and neighboring states are modeled as imports and exports with energy prices provided by a background modeling scenario ("CE-DER").[6] In addition, the transmission capacities between New York and neighboring states are assumed to expand as in the "CE-DER" scenario.

Weather inputs obtained from National Oceanic and Atmospheric Administration (NOAA) High Resolution Rapid Refresh (HRRR) model[7] at 3-km horizontal resolution and 5-minute time resolution are used in WIS:dom-P for applications with load, transmission and most noticeably with the dispatch and placement of solar and wind. The average fixed latitude tilt solar capacity factors and 100-m hub-height wind capacity factors calculated from the

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[3] https://rapidrefresh.noaa.gov/hrrr/
[4] https://www.eia.gov/electricity/data/eia860/
[5] https://www.nyserda.ny.gov/ny/disadvantaged-communities
[6] https://www.vibrantcleanenergy.com/wp-content/uploads/2020/12/WhyDERs_TR_Final.pdf
[7] https://rapidrefresh.noaa.gov/hrrr/

HRRR model output over the model domain are shown in Fig. 1.2. New York's wind resource is highest across the central and western portions of the state along with a significantly strong offshore resource. The solar resource is highest over the whole eastern portion of the state.

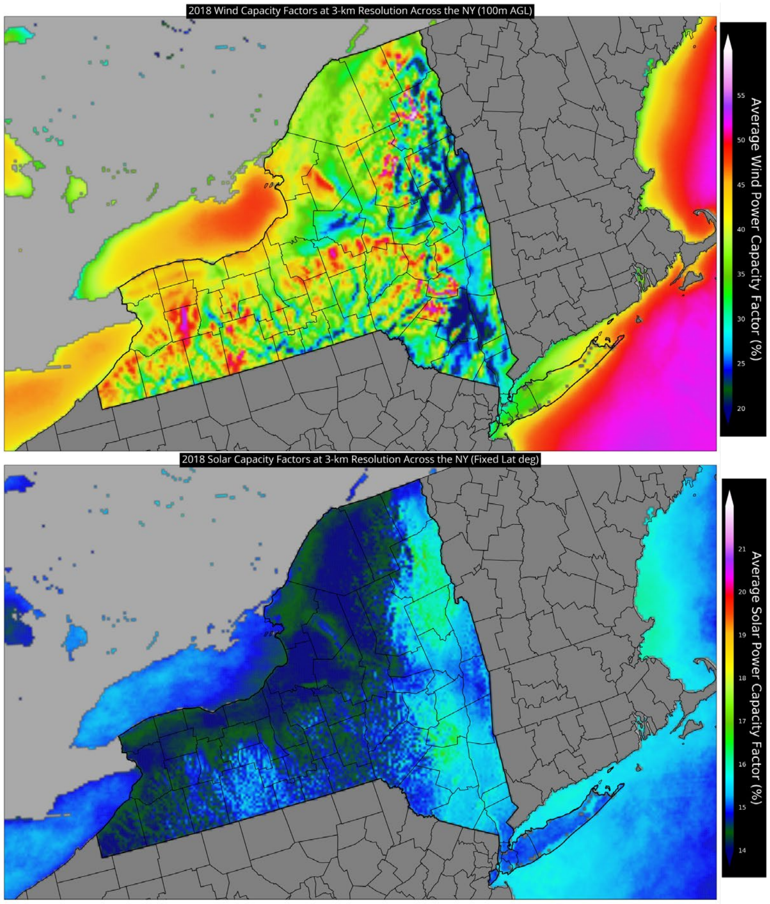

Figure 1.2: Average capacity factors for 100-m hub-height wind (top) and fixed axis latitude tilt solar (bottom) over the state of New York calculated from the HRRR model outputs.

2 Modeling Results

2.1 System Costs, Retail Rates & Jobs

The change in total resource costs and retail rates in New York for the two scenarios modeled is shown in Fig. 2.1. The total resource costs in New York go from about $14 billion in 2020 to $27.8 billion in 2050 in the "Constrained & Non-Optimized DER" scenario. In the "Optimized DER" scenario, the total resource costs are lower in every investment period compared with the non-optimized scenario, reaching $26 billion annually in 2050. Cumulatively, from 2020-2050, the "Optimized DER" scenario saves over $28 billion in total resource costs compared with the "Constrained & Non-Optimized DER" scenario.

In all scenarios, the total resource costs initially decline from 2020[8] to 2025 as New York retires its older fossil fuel generation. After 2025, costs start to increase as demand increases due to electrification and new generation is installed to meet the growing load. The retail rates initially decline from 2020 to 2035 as the more expensive thermal generation is replaced with cheaper variable renewable energy (VRE) generation, as well as imports being reduced as well as the increased system costs are spread over a growing load. Between 2035 and 2040, New York installs large amount of VRE generation along with significant clean dispatchable generation in order to meet New York's 100% decarbonized electricity sector goal resulting in an increase in retail rates due to the significantly increased spending in the electricity sector. After 2040, retail rates reduce again as costs are spread over even higher increased load due to electrification as well as due to some revenues from exports.

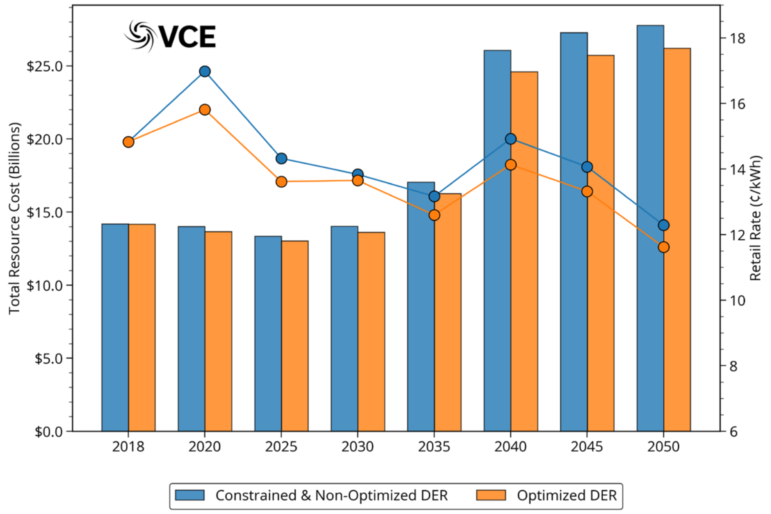

Figure 2.1: Total system cost (bars) and retail rates (solid lines) in New York for the two scenarios modeled.

The annual retail spending in the two scenarios modeled is shown in Fig. 2.2. The retail spending is the cost incurred by customers to pay for electricity used to meet load using the average retail rates. The retail spending declines initially from 2020 to 2025 as retail rates drop, and then increases between 2030 and 2035 as spending shifts to the electricity

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[8] In this modeling, WIS:dom-P is initialized in 2018 and the model outputs results from 2020 to 2050 in 5-year increments.

sector from other sectors due to electrification and the drop in retail rates is not large enough to offset the shift in spending. Retail spending declines from 2045 to 2050 as the reduction in retail rates completely offsets the increased electricity consumption due to electrification. Retail spending in the "Optimized DER" scenario is the lowest of all scenarios throughout the modeling period as co-optimization of the distribution system and ability to leverage distributed generation and distributed storage reduces spending, which is passed on to customers through lower retail rates.

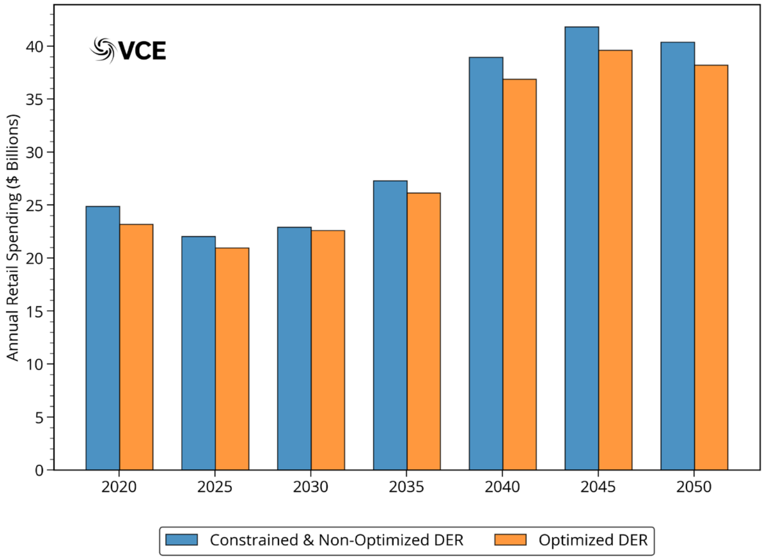

Figure 2.2: Annual retail spending in New York for electricity purchases in the scenarios modeled.

Figure 2.3 shows the energy burden for an average residential and commercial customer in the "Optimized DER" and a "Reference" scenario where the economy-wide energy related activities continue to operate on the current fuel mix and using coal[9], natural gas[10] and oil[11] cost projections from AEO High Oil and Gas Supply scenario. As a result of electrification of economy-wide energy related activities, the average annual energy burden for an average residential and commercial customer reduces by approximately 20% (from $6,906 to $5,563) over the whole modeling period from 2020 to 2050. The energy burden for an average industrial customer reduces by 10% over the whole modeling period. Therefore, electrification of the economy-wide energy related activities reduces average annual spending for all customers compared to not undergoing electrification.

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[9] https://www.eia.gov/outlooks/aeo/data/browser/#/?id=15-AEO2020&region=0-0&cases=highogs&start=2018&end=2050&f=A&linechart=~highogs-d112619a.37-15-AEO2020&map=&ctype=linechart&sourcekey=0

[10] https://www.eia.gov/outlooks/aeo/data/browser/#/?id=13-AEO2020&region=0-0&cases=highogs&start=2018&end=2050&f=A&linechart=~highogs-d112619a.35-13-AEO2020~highogs-d112619a.36-13-AEO2020&map=&ctype=linechart&sourcekey=0

[11] https://www.eia.gov/outlooks/aeo/data/browser/#/?id=12-AEO2020&region=0-0&cases=highogs&start=2018&end=2050&f=A&linechart=~~highogs-d112619a.12-12-AEO2020~highogs-d112619a.17-12-AEO2020&map=&ctype=linechart&sourcekey=0

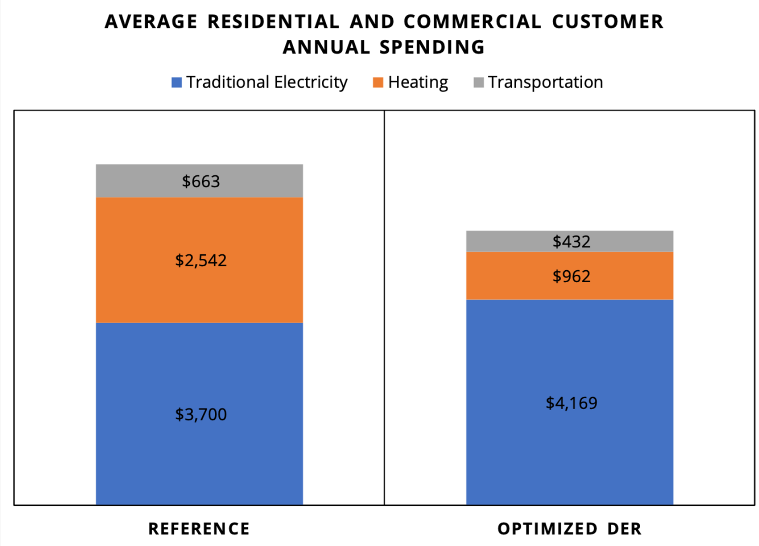

Figure 2.3: Energy burden in the "Optimized DER" scenario compared to the energy burden in the "Reference" scenario of maintaining current fuel mix for economy-wide energy related activities.

The cumulative spending, which includes new capital investment, fixed costs and variable costs, in New York and the DAC regions is shown in Fig 2.4. Spending increases drastically starting in 2035 due to large investments in clean generation to meet the decarbonization goals. Cumulatively around 30% of the spending goes into DAC areas by 2050, in all scenarios. In the "Optimized DER" scenario, more investments are made in distributed resources such as onsite rooftop solar, community solar and distributed storage compared with the non-optimized scenario. As a result, the "Optimized DER" scenario has about 2% additional investments in the DAC regions compared with the non-optimized scenario. These investments in distributed resources in the "Optimized DER" scenario are more likely to stay local and help drive economic development for local populations in addition to the cost savings from co-optimization.

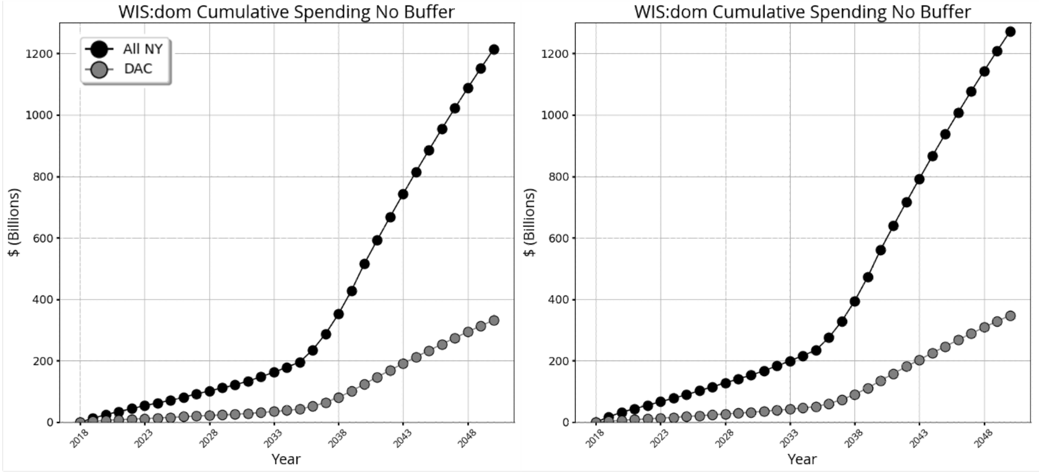

Figure 2.4: Cumulative spending in New York and in the DAC regions in the "Constrained & Non-Optimized DER" scenario (left) and "Optimized DER" scenario (right).

The contributions to the cost per kWh of electricity delivered broken out by sectors in the scenarios modeled is shown in Fig. 2.5. From 2020 to 2035 the cost per kWh delivered drops from 9.82 ¢/kWh to 8.12 ¢/kWh, in the “Constrained & Non-Optimized DER” scenario as a result of replacing fossil fuel generation with renewables and spreading the system costs over an increasing load due to electrification. The drop in energy cost in the “Optimized DER” scenario is higher, reaching 7.8 ¢/kWh by 2035, due to the co-optimized distribution system resulting in significant savings.

Between 2035 and 2040, the cost of energy increases as discussed earlier due to the large deployment of VRE generation to meet New York’s goal of 100% decarbonization of the electric sector by 2040. The “Optimized DER” scenario sees the smallest increase in cost of energy as the optimized distribution system results in savings that offset increases in the rest of the system.

By 2050, the cost of energy in both scenarios declines again as electrification makes more efficient use of installed VRE generation and costs are spread over a greater load. In both scenarios by 2050, the contributions to cost of energy from all sectors of the energy system, except the distribution system, are almost exactly the same. In the “Optimized DER” scenario, the distribution system spending is found to be the lowest both from savings in capital spending and more efficient operation as a result of the co-optimization of the distribution system with the utility-scale generation.

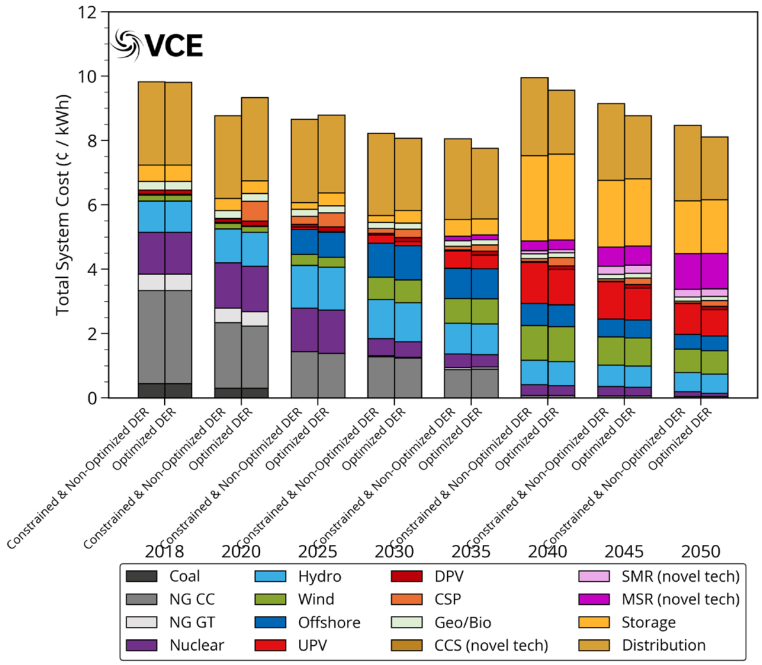

Figure 2.5: Contribution to total system cost per kWh load from each energy system sector for the scenarios modeled.

The total full-time equivalent electricity sector jobs by scenario and technology increase from under 150,000 in 2025 to over 700,000 by 2050 for the state of New York (Fig. 2.6) in the “Optimized DER” scenario. Utility-scale solar and storage (utility-scale and distributed) grow to be the largest technology employers in the state. Distributed generation (onsite rooftop solar and community solar) is also a major contributor to jobs by 2050 in New York, especially when the distributed system is co-optimized in the “Optimized DER” scenario.

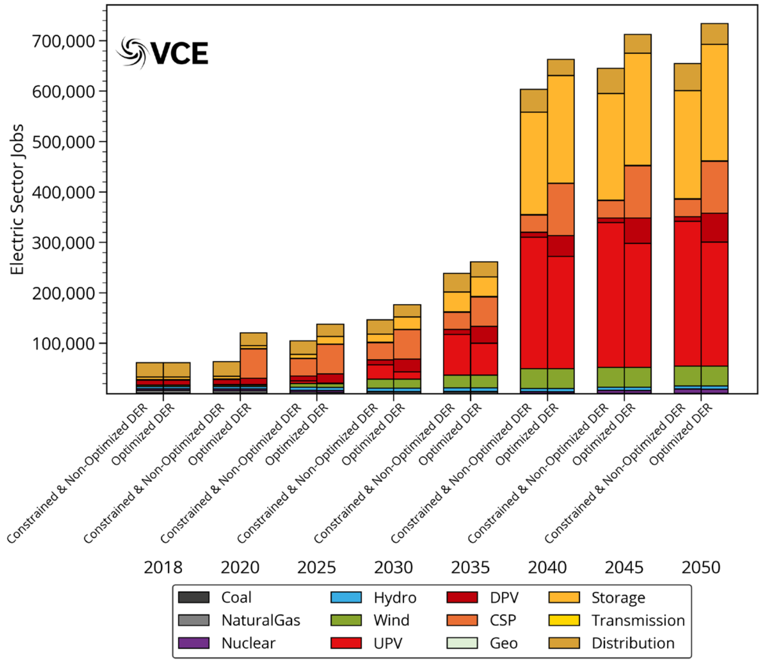

Figure 2.6: Direct full-time equivalent jobs created in the electricity sector by industry for the scenarios modeled.

The full-time equivalent electricity sector jobs by technology in the "Constrained & Non-Optimized DER" and "Optimized DER" scenarios in 2050 split by presence in the DAC regions and rest of New York is shown in Fig. 2.7. The split in location of jobs is made assuming capacity installations create jobs locally. Utility solar creates the largest number of jobs in New York in 2050 of which up to 10% could exist in the vicinity of disadvantaged communities.

The DAC regions see about 56% of all onsite rooftop solar installations and about 12% of community solar installations. In addition, 29% of utility-scale storage and 30% of distributed storage is installed in the DAC regions. Thus, assuming local job creation, the "Optimized DER" scenario results in more jobs and investments in the DAC regions due to larger deployment of DERs compared to the "Constrained & Non-Optimized DER" scenario. The DER installations in the DAC regions not only create local jobs within these regions, but also help keep distribution system costs low in those regions, resulting in positive economic outcomes for the communities in those areas.

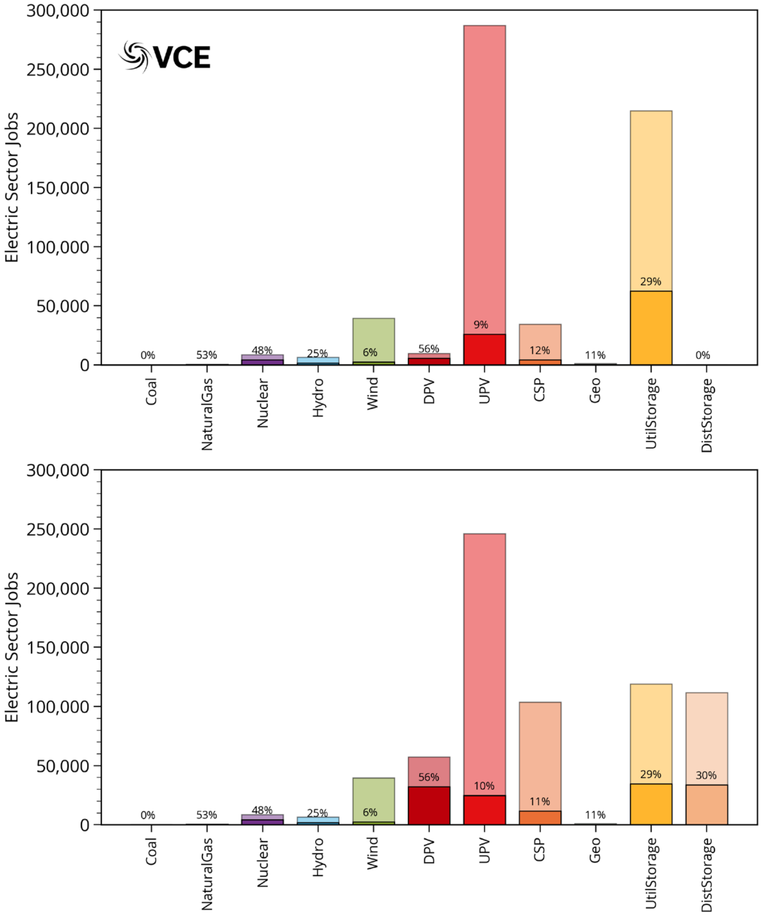

Figure 2.7: Jobs by technology in the “Constrained & Non-Optimized DER” scenario (top) and “Optimized DER” scenario (bottom) and separated by presence in the DAC regions (opaque colors) versus rest of New York (transparent colors).

2.2 Changes to Installed Capacity & Generation

The state of New York undergoes substantial installed capacity turnover to reach deep decarbonization goals and support demand growth from electrification. Figure 2.8 shows the installed capacity and generation by technology in New York over each investment period for the "Optimized DER" scenario. All coal generation in New York is retired by 2025 along with almost half of the natural gas combined cycle (NGCC) and all the natural gas-fired gas turbine (NGGT) generation. The retired fossil fuel capacity is replaced by VREs and storage. About 1.5 GW of new NGGT and 2 GW of NGCC generation is installed between 2025 and 2035 to help storage meet periods of peak load and low VRE generation. By 2040, most of the NGCC generation and all of the NGGT generation is retired and large VRE deployments occur in New York to meet the 100% decarbonized electric sector goal by 2040. By 2050, utility solar produces the most electricity, followed by onshore wind and experimental/novel molten salt reactors (MSR). New York also installs some small modular reactors (SMR) to help provide clean dispatchable generation.

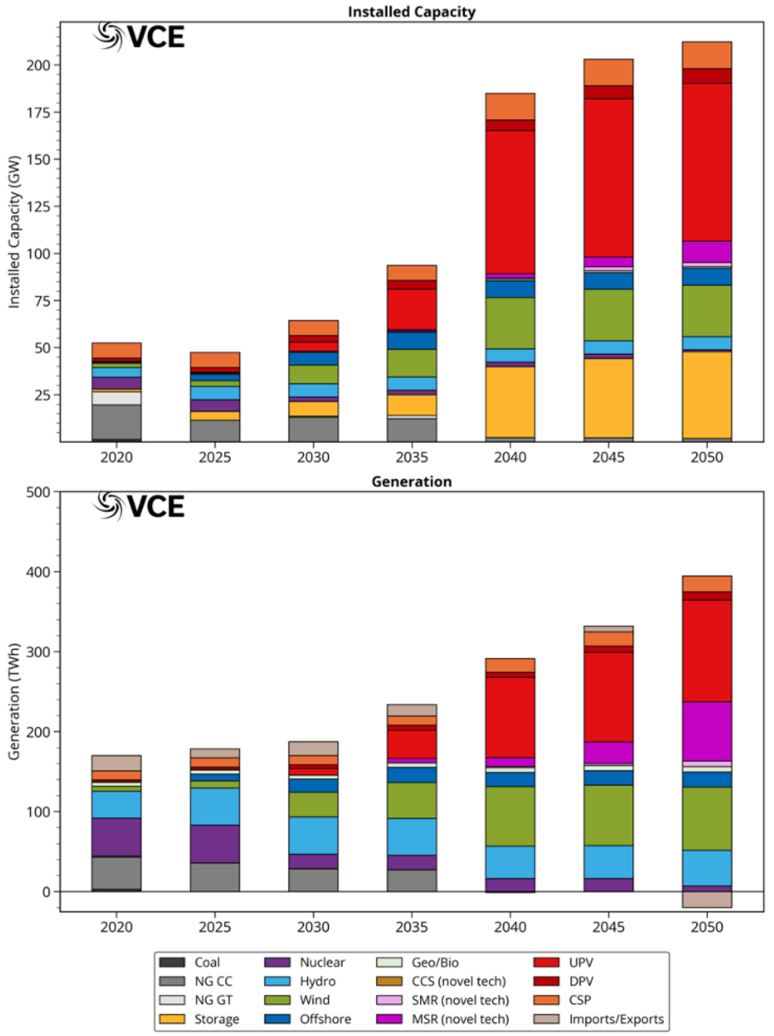

Figure 2.8: WIS:dom-P installed capacities (top) and generation (bottom) for the "Optimized DER" scenario in New York.

The storage power and energy capacities installed in the "Optimized DER" scenario over the investment periods is shown in Fig. 2.9. Until 2035, almost all the new storage installed is in the distribution system to help integrate the onsite rooftop and community solar being installed by the model. After 2035, utility-scale storage installations scale up rapidly to firm up the large VRE generation deployed to meet the 100% decarbonized electric sector goal for 2040. By 2050, distributed storage makes up about a third of the installed storage power capacity and over half of the storage energy capacity. Therefore, the model installs longer duration storage in the distribution system and shorter duration storage on the utility grid.

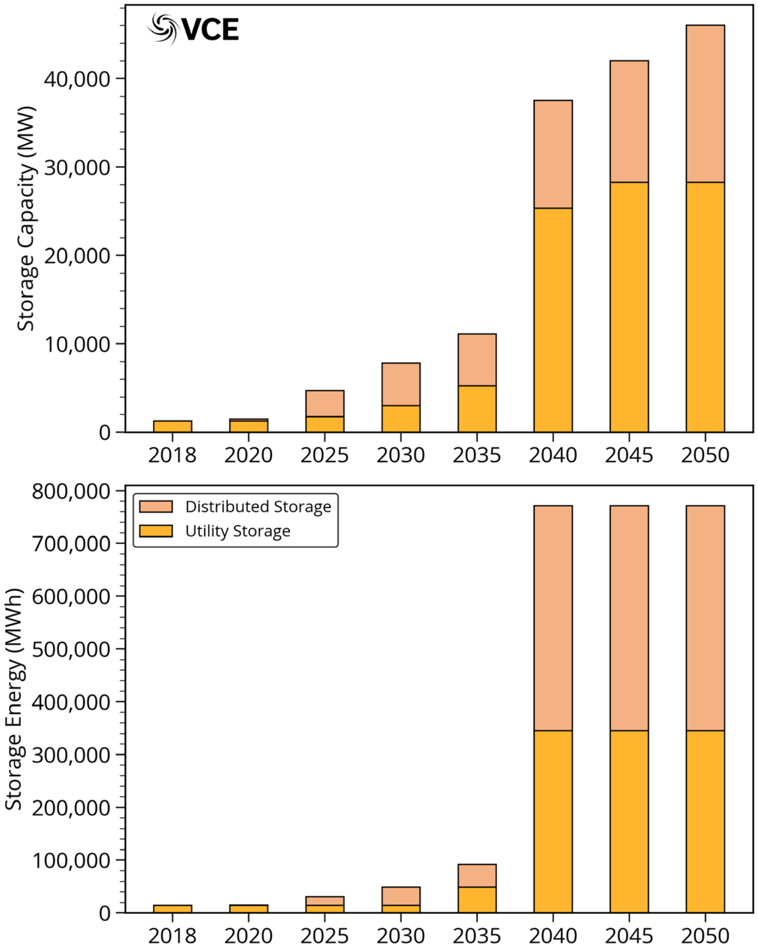

Figure 2.9: Utility storage and distributed storage installed in each investment period for the "Optimized DER" scenario.

The main function of the shorter duration utility-scale storage is absorbing the excess generation from the large utility-scale solar capacity (see Fig. 2.10). This stored energy is moved from the utility-scale storage to the distribution-scale storage during periods of low demand so that the distributed storage is ready to meet demand during peak hours. The distributed storage works with the onsite rooftop and community solar to help meet peak demand during the day and reduce the peak power flowing from the utility-scale grid to the distribution grid resulting in lower expenses in upgrading the distribution system as a result of the growing load due to electrification.

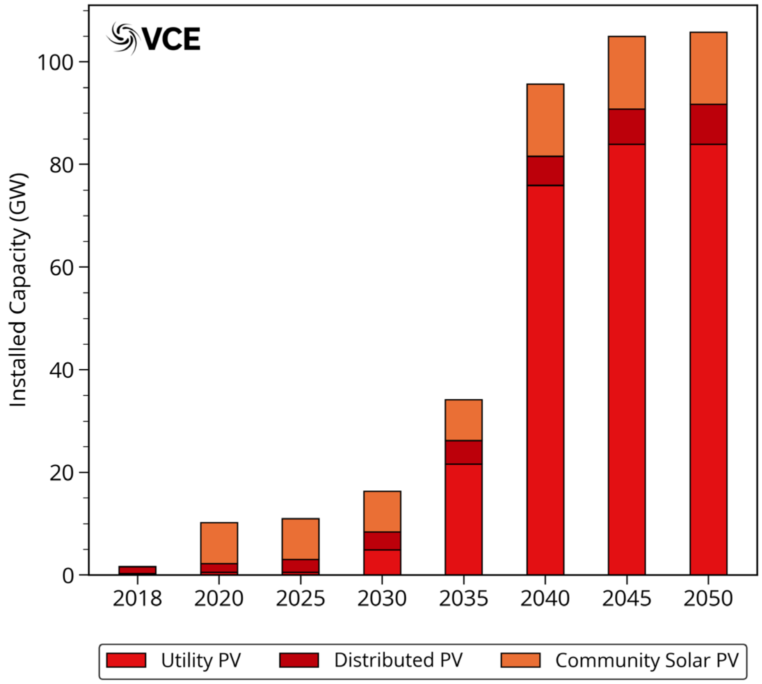

Figure 2.10: Utility PV, Distributed PV and Community PV installed over the investment periods in New York in the "Optimized DER" scenario.

2.3 CO_2 Emissions & Pollutants

The electricity sector emissions and the percentage reductions in economy-wide energy related emissions in the "Optimized DER" scenario from 1990 levels is shown in Fig. 2.11. In the "Optimized DER" scenario, New York reduces its electricity sector emissions to approximately 15 million metric tons (mmT) by 2030 as a result of 70% RPS requirement and then accelerates to decarbonize by 100% by 2040. In addition, as shown in Fig. 2.11 (right panel), the annual economy-wide energy related emissions reduce by 48% compared to 1990 levels (exceeding the 40% reduction requirement) and reduce by 98% by 2050 (exceeding the 85% reduction requirement). As a result of decarbonizing the electricity sector by 100% by 2040, New York saves 425 mmT of carbon dioxide emissions cumulatively by 2050 from the electricity sector. This reduction in emissions is equivalent to removing all vehicle emissions in New York for almost 6 years.

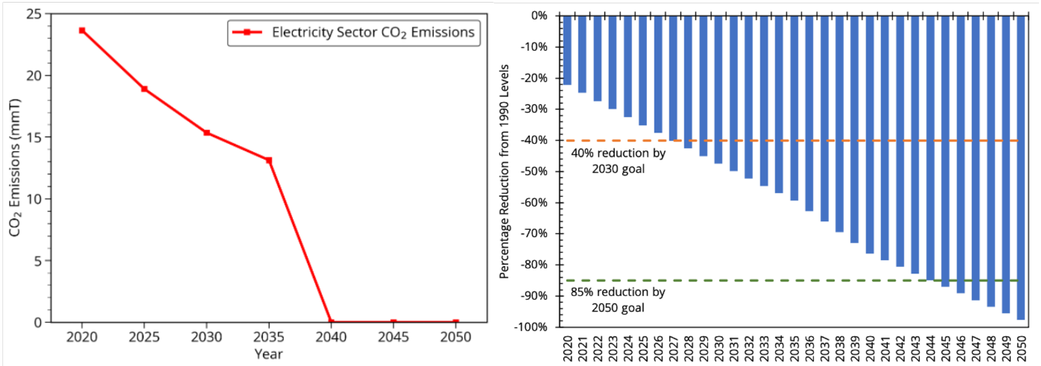

Figure 2.11: Annual electricity sector carbon dioxide emissions (left) and percentage reduction in economy-wide energy related carbon emissions compared to 1990 levels (right).

Electrification of the economy-wide energy related activities along with decarbonization of the electricity sector results in considerable carbon dioxide emission savings in New York. Figure 2.12 shows the cumulative carbon dioxide emissions from economy-wide energy related activities. The grey portion of the plot is additional emissions that would occur if there was no electrification pursued and the rest of the economy continued to emit as it did in 2018 ("Reference" case). Electrification of the economy-wide energy related activities alone saves 2,030 mmT of carbon dioxide emissions cumulatively by 2050 compared with the "Reference" case. Therefore, the combined carbon dioxide emission savings in the "Optimized DER" scenario is 2,455 mmT compared with the "Reference" case of no changes to the rest of the economy or the electricity sector emissions.

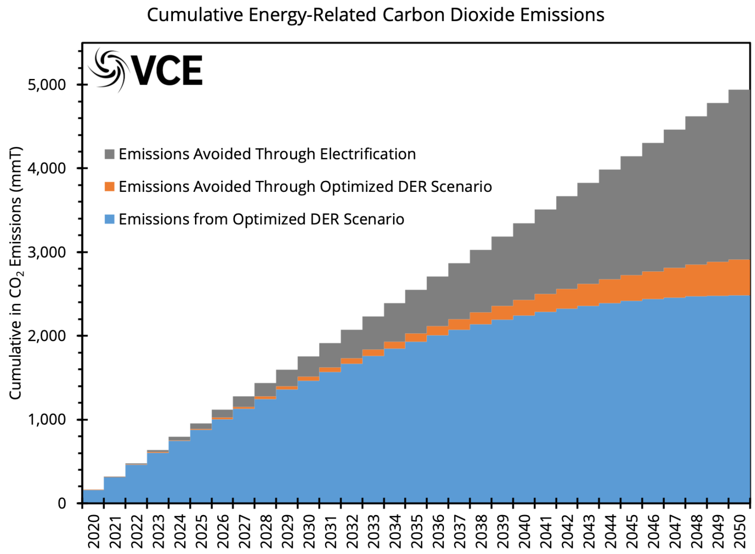

Figure 2.12: Cumulative economy-wide carbon dioxide emission reductions from electrification and the "Optimized DER" scenario.

In addition to reducing carbon dioxide emissions, the "Optimized DER" scenario also reduces emissions of criteria air pollutants emitted by fossil fuel generation. The emissions of air pollutants tracked by WIS:dom-P in the electricity sector are shown in Fig. 2.13. The SO_2 emissions along with PM2.5 and PM10 emissions in the electricity sector go to zero by 2025 as all the coal generation is retired. The emissions of NO_x, along with CH_4, N_2O and VOCs, steadily reduce from 2020 to 2035 as the gas generation is steadily reduced and then reduce sharply to zero by 2040 as the grid decarbonizes completely.

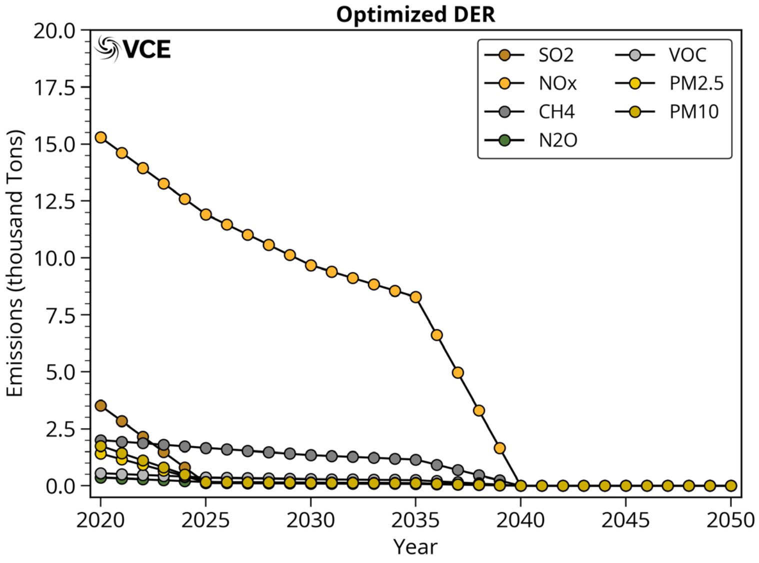

Figure 2.13: Emissions of criteria air pollutants from the electricity sector in the "Optimized DER" scenario.

Figure 2.14 shows the emissions of criteria air pollutants in 2020 in the whole state of New York and the portion in the DAC regions. It is seen that about 40% of the emissions of the criteria air pollutants are emitted within the DAC regions. The DAC regions make up about 7% of the total area of the state of New York. Therefore, the current energy system results in a disproportionate portion of emissions occurring in locations of disadvantaged communities which results in additional burden on these communities in the form of poorer health outcomes from being exposed to these emissions. As the fossil fuel generation is retired from the state of New York, as a result of the decarbonization goal, these communities will see improved health outcomes as a result of better air quality. In addition, the "Optimized DER" scenario makes significant deployments of VREs and distributed generation in the DAC regions. As a result, these regions stand to gain economically from the increased investments in addition to seeing improved health outcomes.

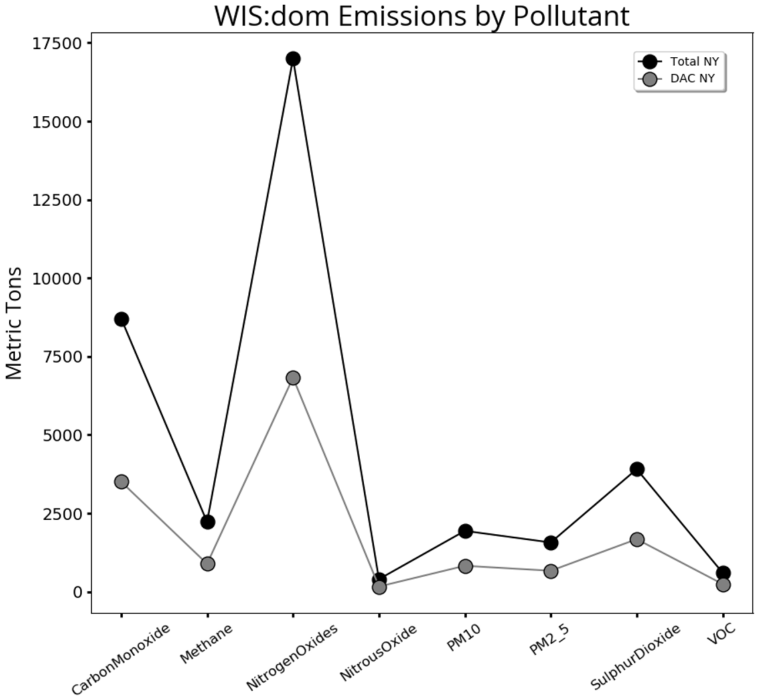

Figure 2.14: Percentage of criteria air pollutants emitted within the DAC regions (grey line) versus total criteria air pollutants emitted in NY (black line) in 2018.

2.4 Siting of Generators (3-km)

WIS:dom-P uses weather datasets spanning multiple years at 3-km spatial resolution and 5-minute temporal intervals over the contiguous United States. WIS:dom-P performs an optimal siting of generators on the 3-km HRRR model grid. The WIS:dom-P installed capacity layout at 3-km resolution along with the transmission paths above 115 kV for 2035 is shown in Figure 2.15 (top panel), while the WIS:dom-P installed capacity by 2050 is shown in Figure 2.15 (bottom panel). The grid is largely transformed to a VRE dominated one by 2035 and has completely emission free generation by 2050.

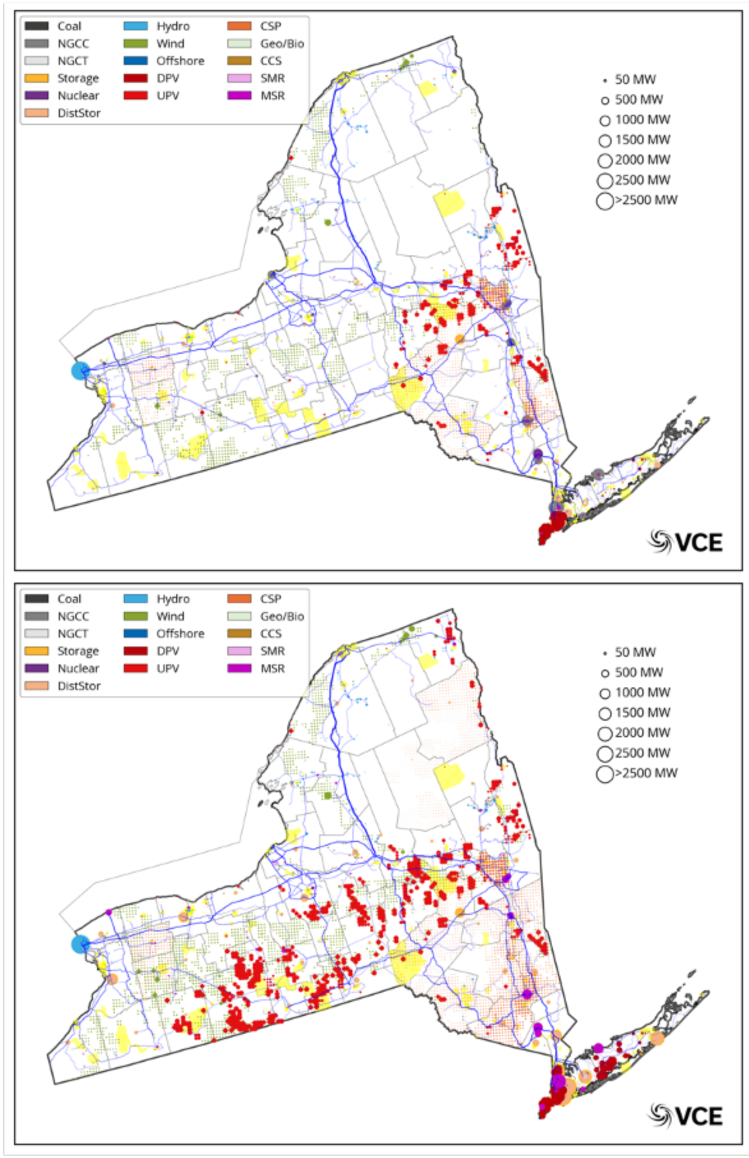

Figure 2.15: Installed generation layout in 2035 (top) and 2050 (bottom) at 3-km resolution along with transmission paths above 115 kV.

It is shown in Fig. 2.15 that onshore wind, offshore wind, utility solar, distributed solar and storage grow significantly throughout the state of New York. Distributed storage and onsite rooftop solar and community solar show up around population centers. Utility solar favors the central portion of the state where the solar resource is slightly better and land is less populated. Distributed solar has a strong presence near the heavy populated regions such as Long Island. Offshore wind is observed in Lake Erie, Lake Ontario and the Atlantic. In addition to these renewable assets, the advanced nuclear Small Modular Reactors (SMR) and Molten Salt Reactors (MSR) technologies are also a part of the firm generator mix by 2050 which help to reach the zero emissions constraints of the scenarios.

When making the siting decisions, the model takes into account several criteria to determine the optimal siting for generators. In addition to accounting for expected generation and distance from the load (for transmission considerations), the model ensures that generation is not sited in unsuitable locations. The model also ensures that the technical potential of each grid 3-km grid cell is not exceeded. The technical potential for the various VRE technologies in each grid cell is determined according to factors such as population, land cover, terrain slope, and others. In addition, each technology is limited by a maximum packing density to ensure that generators do not hamper performance of other generators in the grid cell, such as through wakes for wind turbines and excessive shading for solar panels.