# Economic Impacts of New York's Cap and Invest Plan


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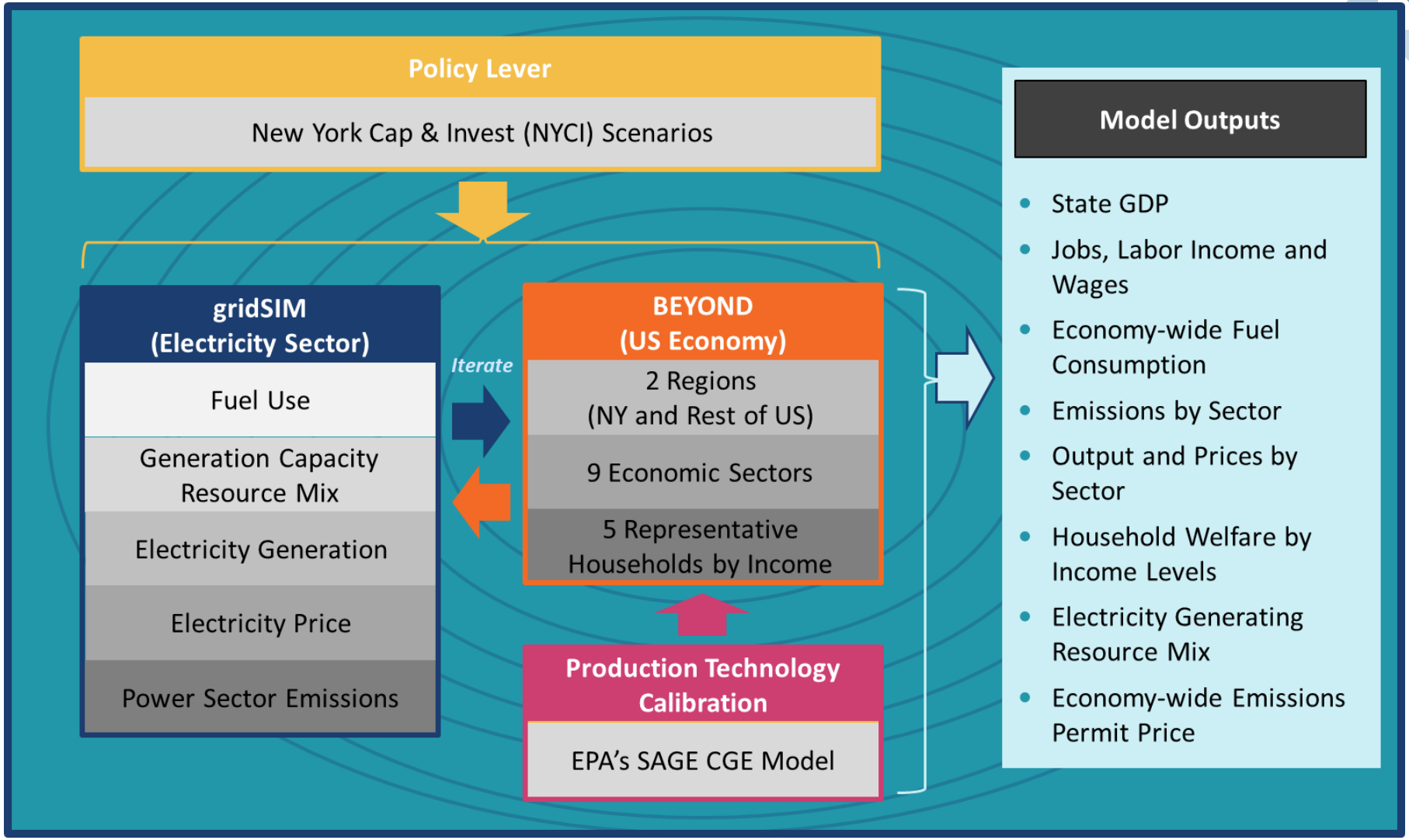
# Modeling Framework:
## gridSIM and BEYOND

# Integrated Modeling Framework: gridSIM and BEYOND

**Brattle's analysis uses an integrated modeling framework that couples two proprietary models:**

- **BEYOND:**
  A dynamic general equilibrium model of the US economy that simulates key interactions between industries, households and government.
- **gridSIM:**
  A detailed electricity sector model that optimizes long-term electricity capacity expansion and simulates hourly market operations, investment, and retirement.

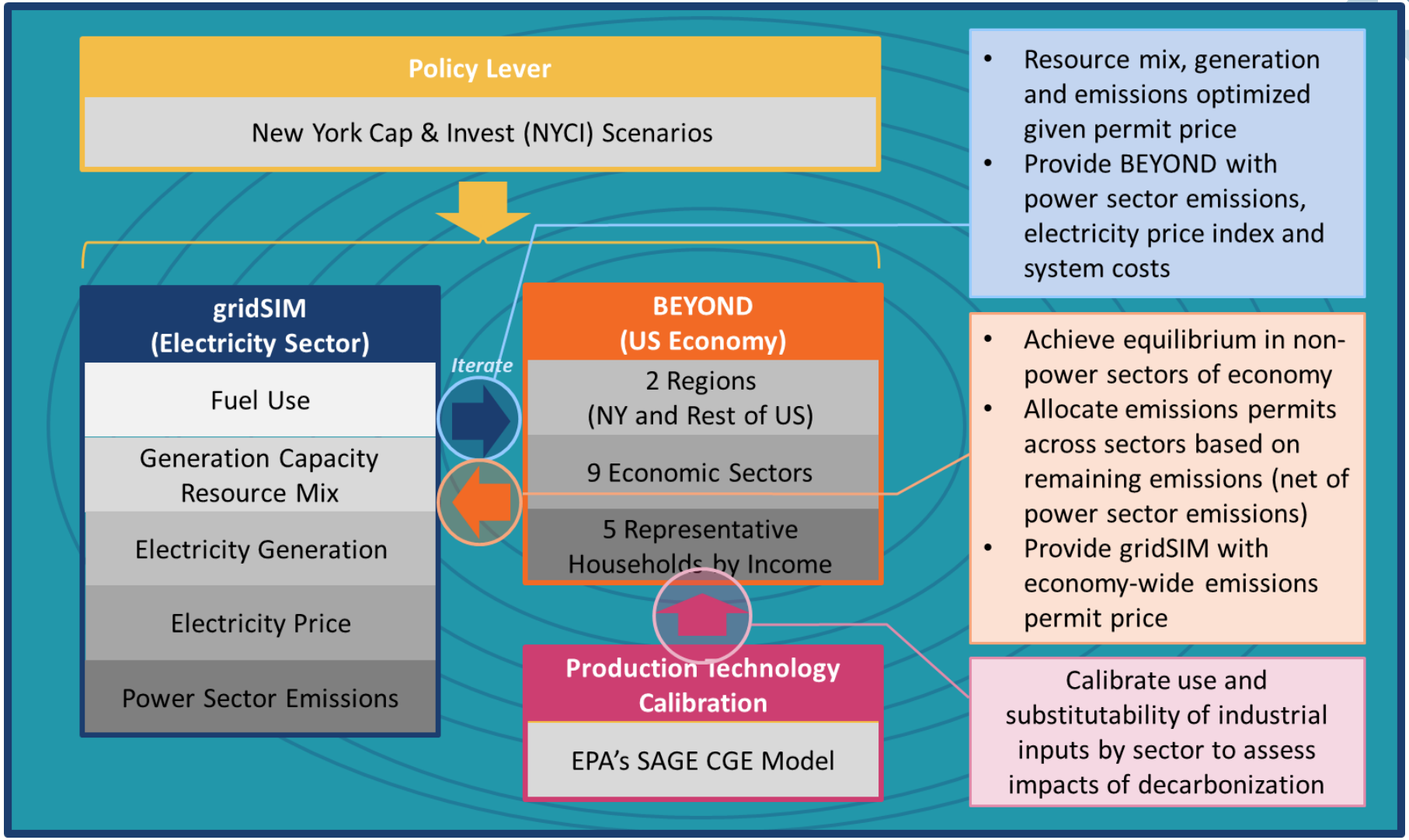


# Integrated Modeling Framework: gridSIM and BEYOND

**Coupling BEYOND and gridSIM provides a comprehensive framework to study the interdependencies between carbon pricing, electricity generation, energy consumption and macroeconomic growth.**

**BEYOND** is used to assess the economy-wide impacts of meeting the carbon cap.

**gridSIM** is used to inform BEYOND's electricity sector on electricity generation, power sector emissions, electricity price, and the generating resource mix procured in each time period.



# Macroeconomic Impact Assessment: **BEYOND**

- BEYOND is Brattle's proprietary recursive dynamic computable general equilibrium (CGE) model
- Representation
  - 50 states + Washington, D.C.
  - 71 sectors based on BEA national summary files
  - 5 household income levels
  - Annual time steps (*2023-2050 for current study*)
- Simulates Key interactions in US economy:
  - Interactions between industries, households and government
  - Model dynamics based on circular flow of economic activity
- Key model outputs:
  - Emissions
  - GDP impacts
  - Price effects (wages, return on capital, prices of goods and services)
  - Economic output by sector and region
  - Consumption of goods and factors of production by sector and region

# Power Sector Expansion Modeling: gridSIM

**gridSIM** has been used in many market design and utility resource planning studies, especially for decarbonization planning. The model optimizes hourly market operations and the expansion of generating capacity and new transmission.

## INPUTS

### Supply
- Existing resources
- Fuel prices
- Investment/fixed costs
- Variable costs

### Demand
- Representative day hourly demand
- Capacity needs

### Transmission
- Zonal limits
- Intertie limits

### Regulations, Policies, Market Design
- Capacity market
- Carbon pricing
- State energy policies and procurement mandates

## gridSIM OPTIMIZATION ENGINE

### Objective Function
- Minimize NPV of Investment & Operational Costs


### Constraints
- Planning Reserve Margin
- Hourly Energy Balance
- Operational Reserve Requirement
- Regulatory & Policy Constraints
- Resource Operational Constraints
- Transmission Constraints

## OUTPUTS

- Annual Investments and Retirements
- Hourly Operations
- Marginal Costs of Capacity, Energy, and Reserves
- System and Customer Costs
- Emissions and Clean Energy Additions
- Supplier Revenues

# Model Calibration

# BEYOND: Input Data Used for Reference Scenario

- **Social Accounting Matrix**
  - Database developed by Wisconsin National Data Consortium (WiNDC), a research group that facilitates the creation and documentation of open source multisectoral economic datasets for US states including emissions data (Rutherford et al., https://windc.wisc.edu/).
- **Production Functions of Supply Sectors**
  - Parameters of sector-specific production functions in BEYOND are calibrated to parameters used in the US Environmental Protection Agency's SAGE model.
- **GDP Growth and Macroeconomic Indicators (2022-2050)**
  - GDP growth in BEYOND's regions in US calibrated to EIA's projection of US GDP growth based on Annual Energy Outlook 2023 (AEO 2023).
  - Economic growth of end-use sectors (e.g., residential, transportation, industrial sectors), energy consumption and emissions are also calibrated using AEO 2023.
  - New York's economic growth and emissions calibrated to NYSERDA's Pathways Integration Analysis Reference case (2023).

# gridSIM: General Data Inputs

- gridSIM-NYISO uses data sources specified in table.
- EGUs near disadvantaged community census tracts (DACs) are represented by technology type and NYISO zone (*gridSIM operates at power zone granularity*).
- Relevant resource types in gridSIM's resource mix are disaggregated into two types – those that are sited in/near DACs (referred to as DAC units) and those that are not.

| Model Feature | Source/Description |
|---|---|
| Zones | *Aggregated NYISO zones (Zone A-E, Zone GHI, Zone J, Zone K)* |
| Transmission topology and limits | *NYISO Installed Reserve Margin (IRM) 2023 Document* |
| Existing generator data | *NYISO Goldbook 2023* |
| Fuel prices | *EVA Forecast 2021* |
| New generator costs | *NREL ATB 2023* |
| Hourly renewable generation shapes | *NREL Renewable Energy Potential Model scaled to historical capacity factors* |
| Hourly load shapes | *FERC 714 filing via S&P Global Market Intelligence (2019)* |
| Load growth | *NYISO Goldbook 2021; Brattle base load growth scenario* |
| Zonal capacity requirements | *NYISO Goldbook 2021; Brattle forecast* |
| Imports and exports | *Benchmarked to historical NYISO import/export flow* |
| RPS | *70% renewable by 2030, 100% clean by 2040* |
| Carbon limit | *None* |
| Carbon price | *RGGI carbon price* |
| Storage efficiency | *85%* |
| Tax credits | *Consistent with Inflation Reduction Act* |
| Representative Days | *Each model year has distinct 25 representative 72-hour periods* |
| Modeled years | *Every two years from 2020-2052* |
| ELCC | *OSW, LBW, Solar, Storage calculated independently based on load and profiles* |

# Modeling CES: Clean Energy Build Timeline and Constraints

| Technology | First Year for Economic Builds | Build Limit | Additional Notes |
|---|---|---|---|
| Offshore Wind | 2028 | 6,000 MW/per modeled year (every 2 years) | |
| Onshore Wind | 2026 | | |
| Solar | | | |
| 2-hr Battery Storage | | | |
| 4-hr Battery Storage | | | |
| Combined Cycle | | | Allow burning of zero-carbon fuels starting in 2030. Variable costs and fuel costs are consistent with NYISO's LcHo DEFR resource. |
| Combustion Turbine | | | |

| Year | 70x30 Renewable Generation (%) | 100x40 Clean Generation (%) | Offshore Wind MW | Distributed Solar MW | Energy Storage MW |
|---|---|---|---|---|---|
| 2025 | 38% | 0% | 900 | 6,000 | 3,000 |
| 2030 | 70% | 70% | 2,400 | 10,000 | 6,000 |
| 2035 | 70% | 85% | 9,000 | 10,000 | 6,000 |
| 2040 | 70% | 100% | 9,000 | 10,000 | 6,000 |

Sources and Notes:

- Renewable technologies that can contribute to 70x30 RPS Requirement include wind (onshore and offshore), solar (utility scale and BTM), and Hydro.
- 100% Clean Electricity by 2040 mandate calculated as (1-%Emission Free) * Load * (NGCC Emission Rate)
- 70% by 2030 RPS from New York Senate Bill S6599.
- 100% by 2040 Mandate from NY CLCPA.
- Solar Mandates from 2019 Gold Book Forecast.
- Offshore Wind Mandates from NYSERDA, Toward A Clean Energy Future: A Strategic Outlook 2020-2023.
- Storage mandate based on latest announcement to increase storage goal to 6 GW by 2030
- Targets are linearly extrapolated between starting, mid, and end targets, though model can over-build to meet other needs as necessary.

# Representation of Imports in gridSIM

In this exercise, only the NYISO is represented in full system detail. Adjacent markets are represented as aggregates with import/export capability and given carbon intensities:

- Imports from PJM, ISO-NE, and IESO are modeled as emitting generation, while imports from Hydro-Quebec are treated as carbon-free.
- Level of imports are benchmarked against historical import and export flows.
- Respective carbon intensities of imports are kept constant at historical levels.
  - This assumes no change to the supply mix of neighboring regions, or changes in state or RTO/ISO policies with respect to their own decarbonization goals. This also does not account for those regions' commitments to clean energy supply mix in the future (e.g., state offshore wind or RPS targets). Results may therefore be conservative but focus on what NY can do regardless of adjacent regions.
  - Representative emissions rates for regional imports are calculated based on the generation-weighted annual average emissions rate for all units in the region.

# Modeling the Peaker Rule

- gridSIM models 1195 MW of forced peaker CT retirements as follows:
  - Zone G: Coxsackie, South Cairo units retiring in 2023
  - Zone J: Narrows Generating, Gowanus Gas Turbine Units various retirements in 2023-2025
  - Zone K: Northport, Port Jefferson, Shoreham, etc. retirements in 2023
- gridSIM's approach is consistent with the ~1150 MW of peaker CT retirements shown below
  - NYISO indicates ~800 MW of CT's scheduled to be out of service by 2025
  - A study by NYPA indicates an additional 350 MW feasible for full replacement by 2030

**Table IV-6: Proposed Generator Status Changes to Comply with DEC Peaker Rule [1]**

| OWNER / OPERATOR | STATION UNIT | ZONE | DATE | PTID | CRIS (MW) SUMMER | CRIS (MW) WINTER | CAPABILITY (MW) SUMMER | CAPABILITY (MW) WINTER | Notes |
|---|---|---|---|---|---|---|---|---|---|
| Central Hudson Gas & Elec. Corp. | Coxsackie GT | G | 05/01/2023 | 23611 | 21.6 | 26.0 | 19.0 | 23.6 | 2 |
| Central Hudson Gas & Elec. Corp. | South Cairo | G | 05/01/2023 | 23612 | 19.8 | 25.9 | 18.7 | 23.1 | 2 |
| National Grid | Northport GT | K | 05/01/2023 | 23718 | 13.8 | 18.0 | 8.3 | 12.7 | 2 |
| National Grid | Port Jefferson GT 01 | K | 05/01/2023 | 23713 | 14.1 | 18.4 | 13.0 | 15.3 | 2 |
| National Grid | Shoreham 1 | K | 05/01/2023 | 23715 | 48.9 | 63.9 | 41.3 | 61.4 | 2, 4 |
| National Grid | Shoreham 2 | K | 05/01/2023 | 23716 | 18.5 | 23.5 | 16.5 | 20.3 | 2, 4 |
| National Grid | Glenwood GT 03 | K | 05/01/2023 | 23689 | 54.7 | 71.5 | 49.9 | 67.2 | 2, 4 |
| Consolidated Edison Co. of NY, Inc. | 59 St. GT 1 | J | 05/01/2025 | 24138 | 15.4 | 20.1 | 13.1 | 18.8 | 2 |
| NRG Power Marketing, LLC | Arthur Kill GT 1 | J | 05/01/2025 | 23520 | 16.5 | 21.6 | 12.3 | 15.8 | 2 |
| Astoria Generating Company, L.P. | Gowanus 2-1 through 2-8 | J | 05/01/2025 | 24114-24121 | 152.8 | 199.6 | 142.1 | 182.0 | 3 |
| Astoria Generating Company, L.P. | Gowanus 3-1 through 3-8 | J | 05/01/2025 | 24122-24129 | 146.8 | 191.7 | 136.9 | 179.9 | 3 |
| Astoria Generating Company, L.P. | Narrows 1-1 through 2-8 | J | 05/01/2025 | 24228-24243 | 309.1 | 403.6 | 285.9 | 369.2 | 3 |
| | | | | **Total** | **832.0** | **1,083.8** | **757.0** | **989.3** | |

Source: NYISO, 2023 Goldbook: Table IV-6. Published April 2023. This table outlines the proposed status changes of simple-cycle combustion turbines to comply with the DEC Peaker Rule.

*Table 4: Overview of SCPP Site Characteristics*

| Site Name | Borough | SCPP Capacity | Total Land Area |
|---|---|---|---|
| Harlem River Yards* | Bronx | 79.9 MW | 1.8 acres |
| Hell Gate* | Bronx | 79.9 MW | 2.6 acres |
| Kent (AKA North 1st) | Brooklyn | 47 MW | 1.4 acres |
| Vernon Boulevard | Queens | 79.9 MW | 3.2 acres |
| Joseph J. Seymour* (AKA Gowanus) | Brooklyn | 79.9 MW | 1.7 acres |
| Pouch Terminal | Staten Island | 47 MW | 1.1 acres |

*Identified as a high priority for adaptation due to site characteristics and its location in disadvantaged communities.

Source: NYPA, SCPP Adaptation Study. Published April 2022.

# Modeling RGGI

- In all reference and policy cases, the RGGI price trajectory is held constant.
- The RGGI price path for 2022-2035 is derived from ICF's Integrated Planning Model (IPM) modeling for RGGI Inc., Scenario B, reflecting a RGGI cap consistent with 100% decarbonization by 2040 (0X40); and achievement of CES/RPS targets in RGGI states.
- Prices after 2035 are extrapolated based on modeling of a 0x40 RGGI policy scenario conducted by ERM (FACETS model) for EDF
- The effective carbon price in all scenarios is the higher of the NYCI or RGGI price
- A price trajectory is used as a proxy for RGGI but an emissions cap on the RGGI region is not explicitly modeled

**RGGI Price (Nominal $/ton)**

| Year | Price |
|---|---|
| 2022 | $2.40 |
| 2024 | $2.55 |
| 2026 | $2.69 |
| 2028 | $2.83 |
| 2030 | $2.98 |
| 2032 | $3.13 |
| 2034 | $3.28 |
| 2036 | $7.65 |
| 2038 | $16.24 |
| 2040 | $24.83 |

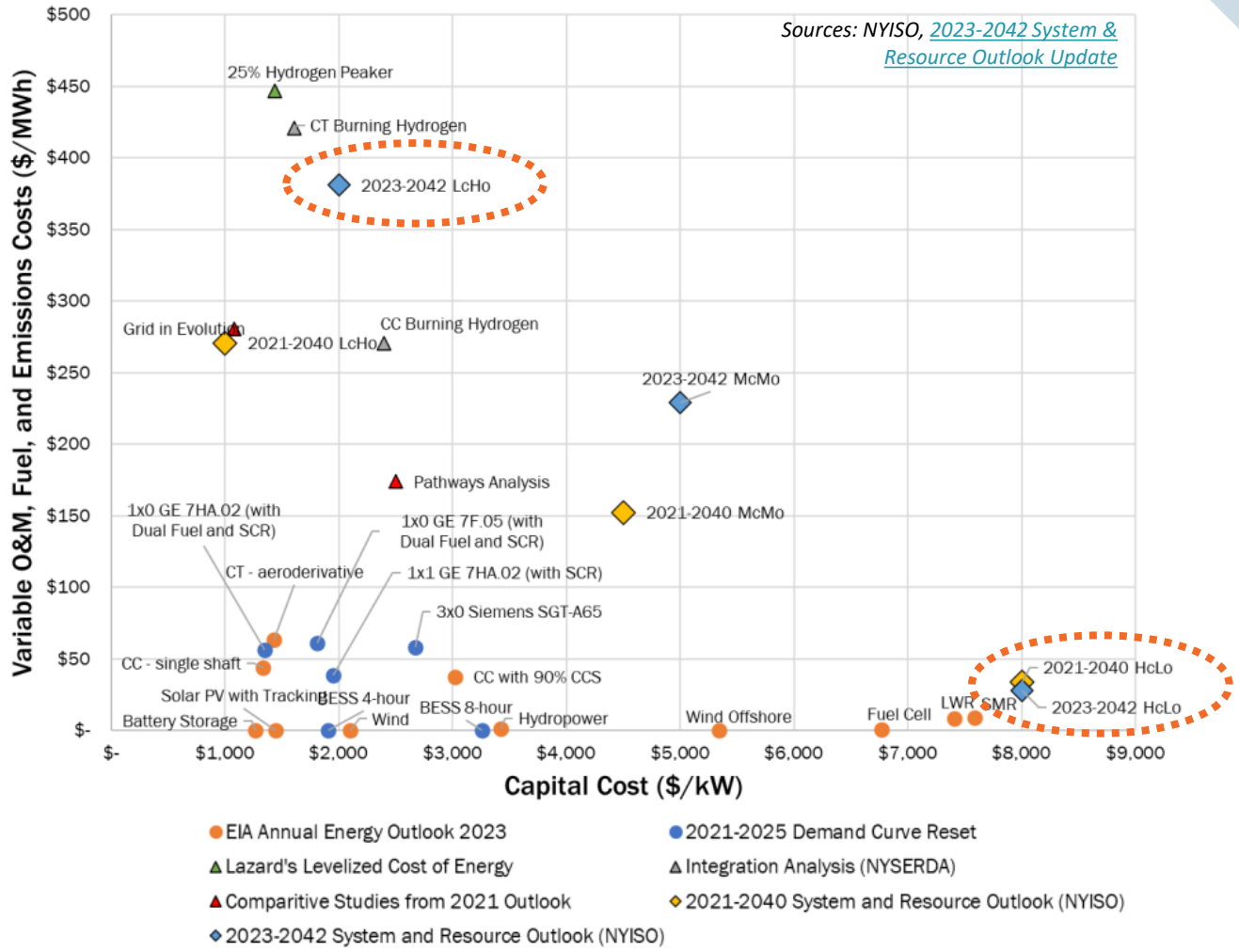
# Modeling Dispatchable Emission-Free Resources (DEFRs)

DEFR is a representative class of resources that will meet the flexibility and emissions-free energy needs.

Two resource classes modeled in gridSIM representing potential future technologies, aligned with NYISO estimates:

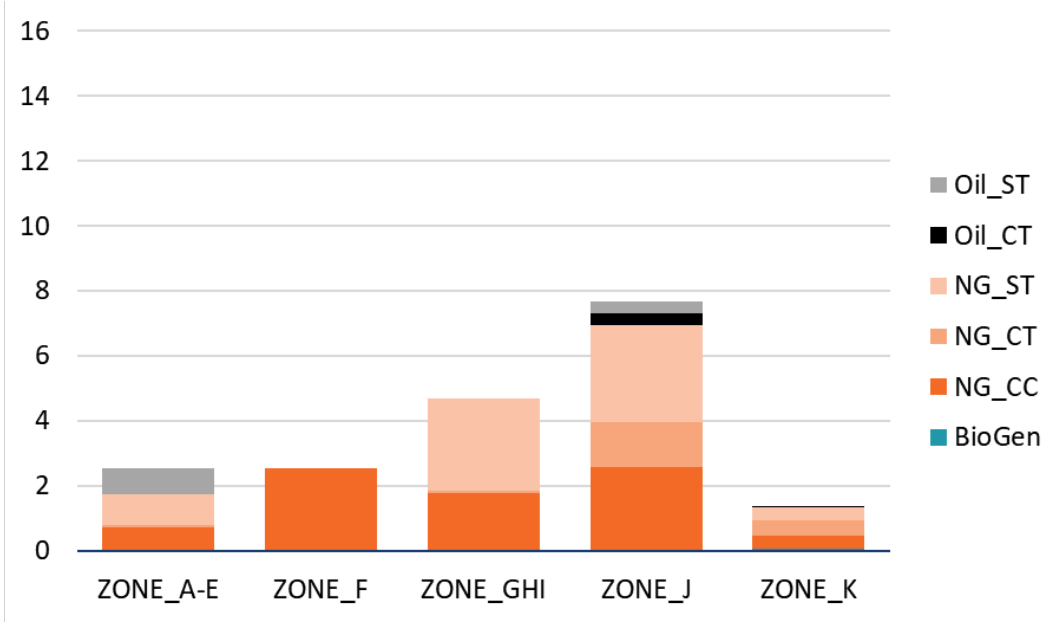
- DEFR-LcHo
  - Low capital cost, high operating cost
  - E.g., Gas combined cycle units burning Hydrogen
- DEFR-HcLo
  - High capital cost, low operating cost
  - E.g., Small Modular Reactors (SMRs)

## NYISO Generator Capital Cost vs. Variable Costs

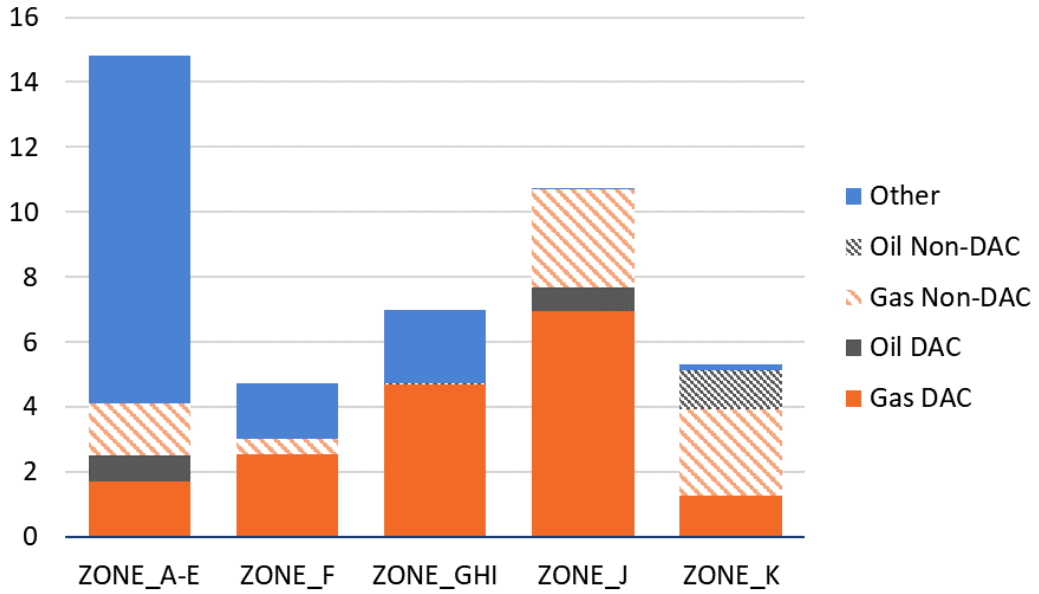


# Representation of EGUs in or near Disadvantaged Communities

## NYISO Installed Capacity of DAC Units in 2022 (GW)




## NYISO Total Installed Capacity in 2022 (GW)




### Capacity-Weighted Average Heat Rate (MMBtu/MWh)

*DAC vs Model Average*

| Unit Type | Model Heat Rate | DAC Heat Rate |
|---|---|---|
| NG_CC | 7,438 | 7,520 |
| NG_CT | 12,795 | 13,650 |
| NG_ST | 10,665 | 10,769 |
| Oil | 12,380 | 12,032 |

*Sources: Units are determined to be near DAC's through spatial analysis of Title V permitted EGUs within one mile of a DAC Census Tract conducted by EDF. Unit capacity is taken from NYISO GoldBook.*

DAC Capacity = 18.7 GW

*17.1 GW Gas, 1.5 GW Oil, 0.1 GW Bio*

*69% of NYISO's fossil-fueled capacity*

*44% of NYISO's Total Capacity*

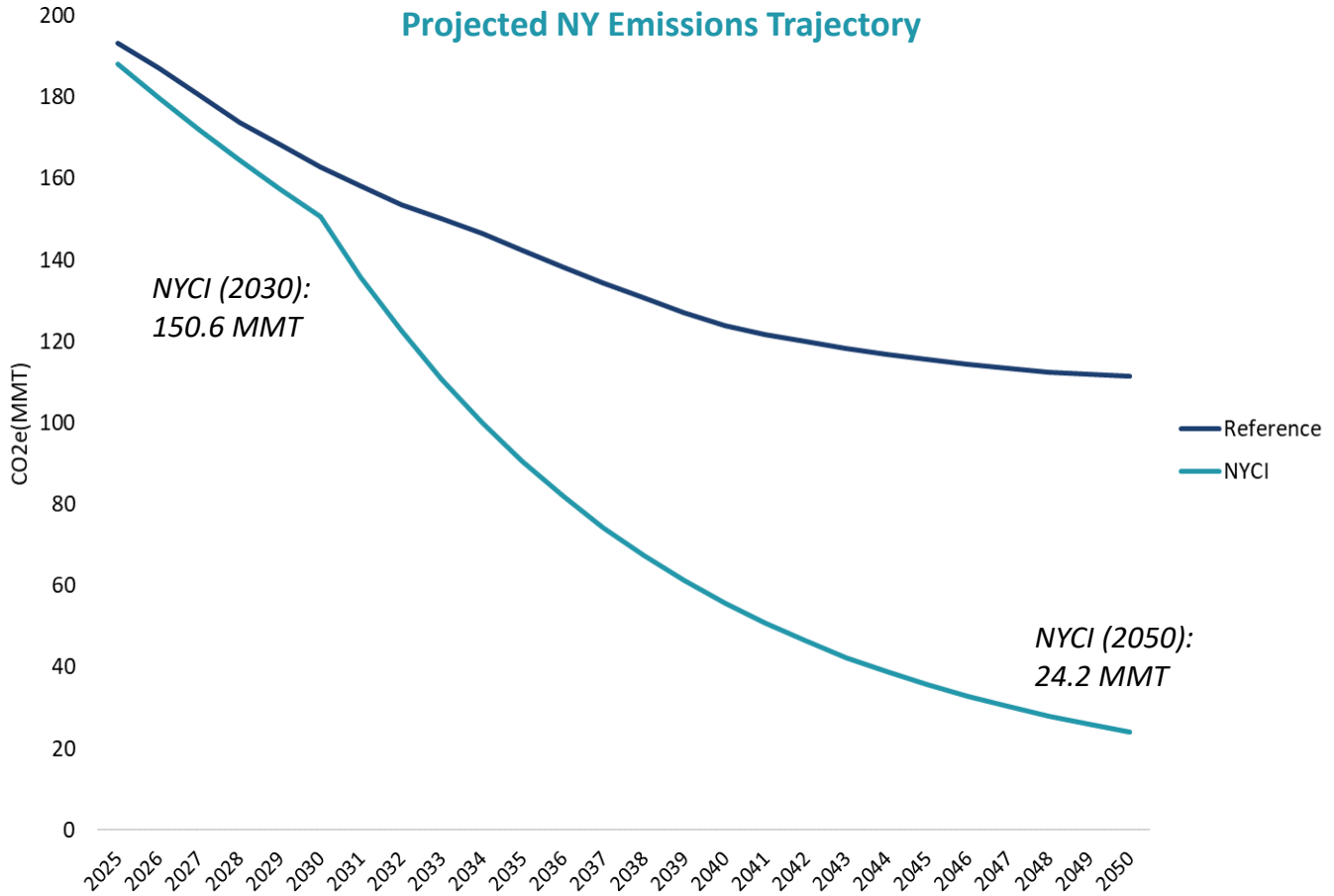
Total NYISO Capacity = 42 GW

# Modeling NYCI Revenue

- Investment allocation of total permit revenue generated is consistent with the percentage split specified in NYSERDA's New York Cap-and-Invest (NYCI) Preliminary Scenario Analysis. The revenue allocation is as follows:
  - **Affordability Accounts** (*Transfer to Households*): **30%**
  - **Climate Investments: 70%**
    - 30% of Investment Allocated to Transportation
    - 70% of Investment Allocated to Commercial and Residential Buildings
- Economy-wide emissions results presented in this analysis accounts for the revenue investment.

# Modeling NYCI

- Industrial, electricity, transportation, buildings, and waste sectors are obligated; agriculture and aviation non-obligated
- For obligated sectors, emissions allowances are modeled to decrease by 4.6%/yr between 2025-2030 to reach the 2030 target, thereafter decreasing by 10.4%/yr to approach the 2050 target.*
- Emissions in BEYOND represents CO2e ($CO_2$, $CH_4$, $N_2O$) from burning fossil fuels.
- Gross emissions factors consistent with NY accounting are used.**
- Allowance banking – which is likely to decrease total program costs over a given period – is not modeled.




* Obligated emissions budgets are based on the NY DEC 2022 Statewide GHG Emissions Report. Obligated budgets for 2030 and 2050 are derived to reflect 40% and 85% below 1990 levels respectively and are adjusted for non-obligated sector performance based on NYSERDA's Integration Analysis, Scenario 3. The starting year budget for 2025 is based on a linear interpolation of a straight-line emissions pathways from 2019 historical emissions levels for obligated sectors to the 2030 target. A separate pathway is interpolated between 2030 and 2050.

** "Fossil and Biogenic Fuel Greenhouse Gas Emission Factors" report (NYSERDA, 2023)

# Reference Case & Policy Cases

## Reference case assumptions for the electricity sector:

- State meets the 70% renewable generation target by 2030, but not the 100% carbon free electricity target by 2040.
  - This assumption was made to explore the potential role of NYCI in incentivizing emissions abatement in the power sector as a backstop to the CES.
- Clean energy builds track existing technology-specific requirements
- RGGI price trajectory is aligned with IPM Scenario B (0x40 with achievement of state CES targets).
- Cap on the annual increase in DEFR generation applied. An annual increase of 6.8 GWh is implemented based on the NYISO's 2021-2040 System & Resource Outlook, Appendix F.

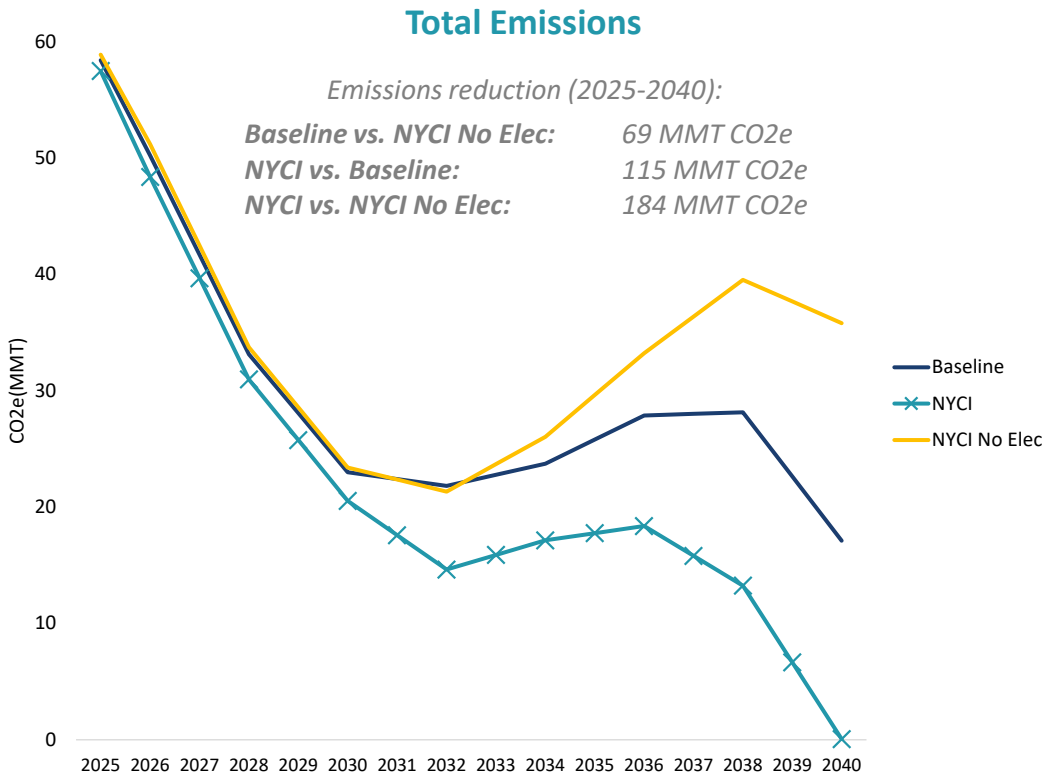
## Two policy cases are then modeled:

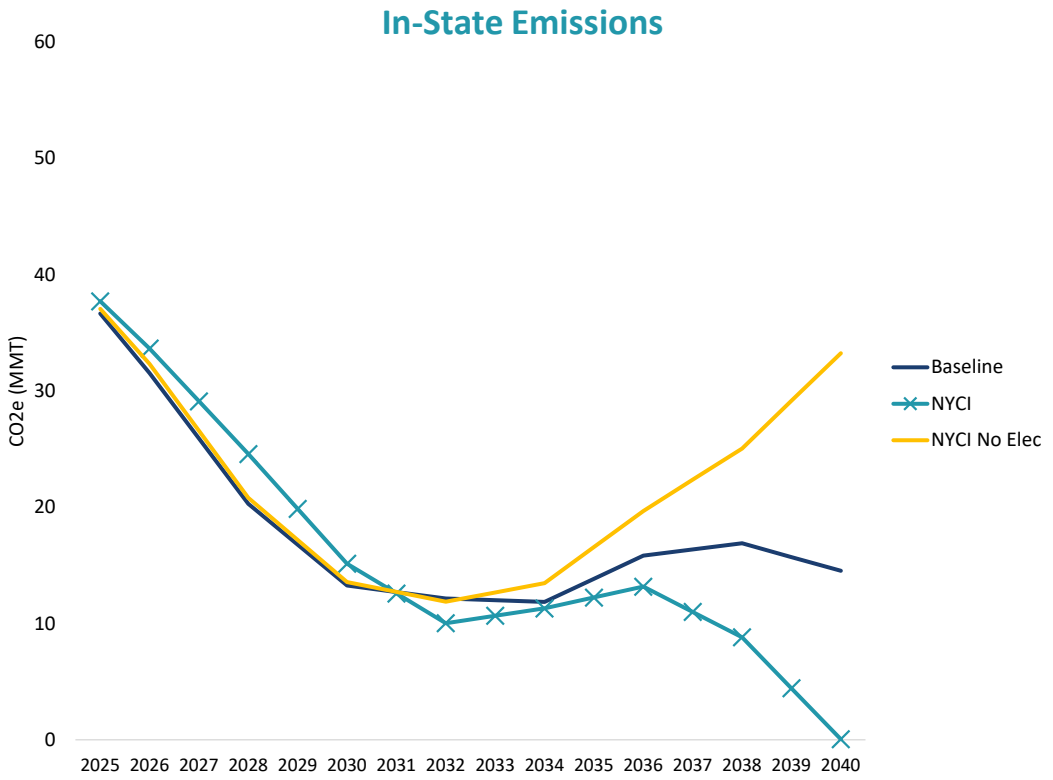
- "NYCI": NYCI program obligating electricity as well as transportation, buildings, industrial, and waste sectors
- "NYCI No-Elec": NYCI program that does not obligate electricity but still obligates all other sectors included in "NYCI" Scenario

# NYCI Scenario Results: Power Sector

# Power Sector Emissions

**Under NYCI, permit prices incentivize the switchover to carbon-free resources and drive power sector emissions to zero by 2040:** Electricity sector emissions when sector is not obligated under NYCI are higher than the baseline due to higher electricity demand. In-state emissions increase slightly in the near-term in the NYCI scenario, as in-state generation displaces imports that have higher emissions rates.*



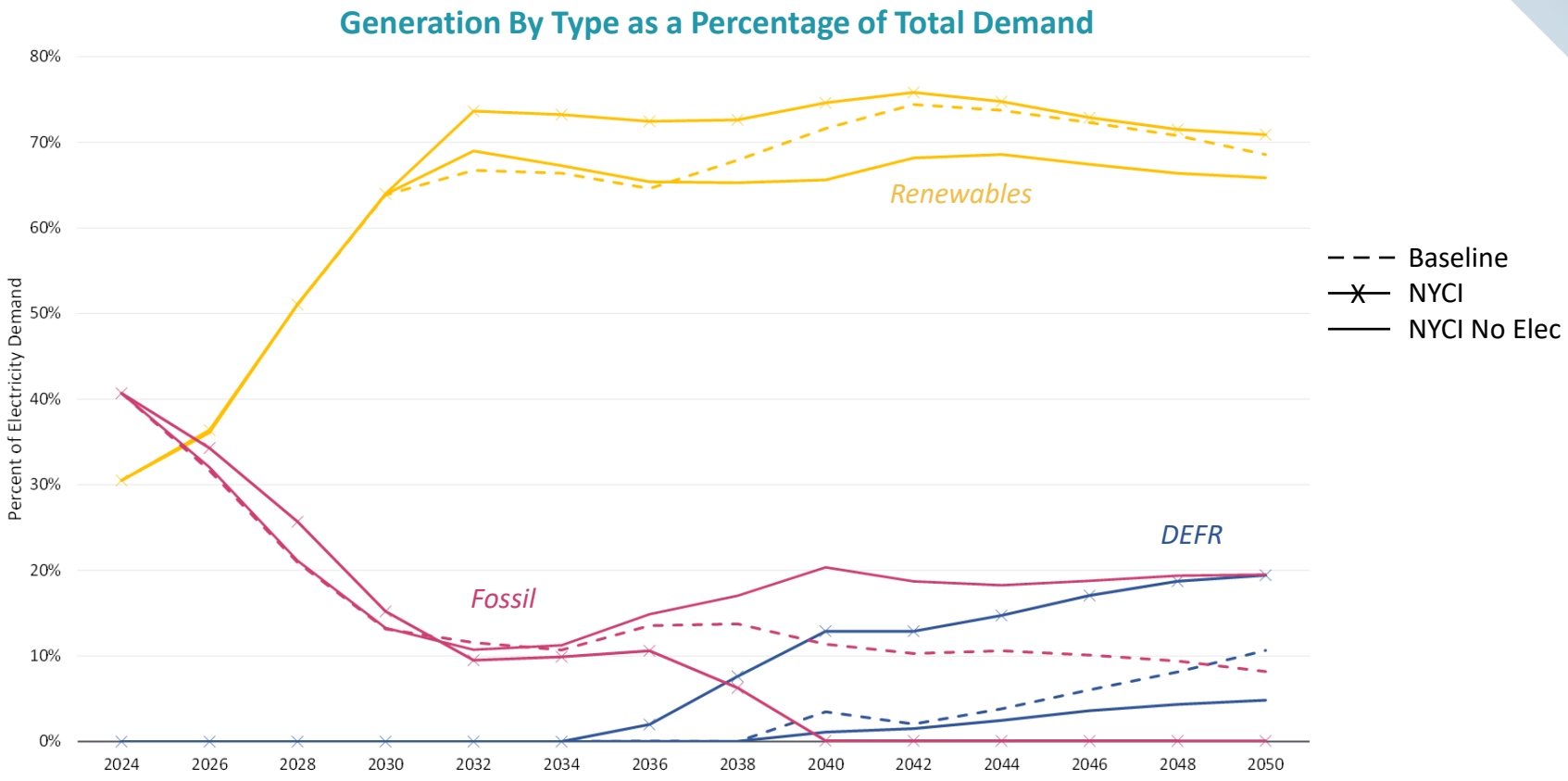




* Analysis keeps emissions intensity of imports constant at historical levels.

# In-State Generation by Type

Renewable and DEFR penetration is highest under NYCI, compared to the reference and Electricity not obligated NYCI scenarios.

In-state fossil generation remains around 20% of the generation mix through 2050 when Electricity is not obligated.

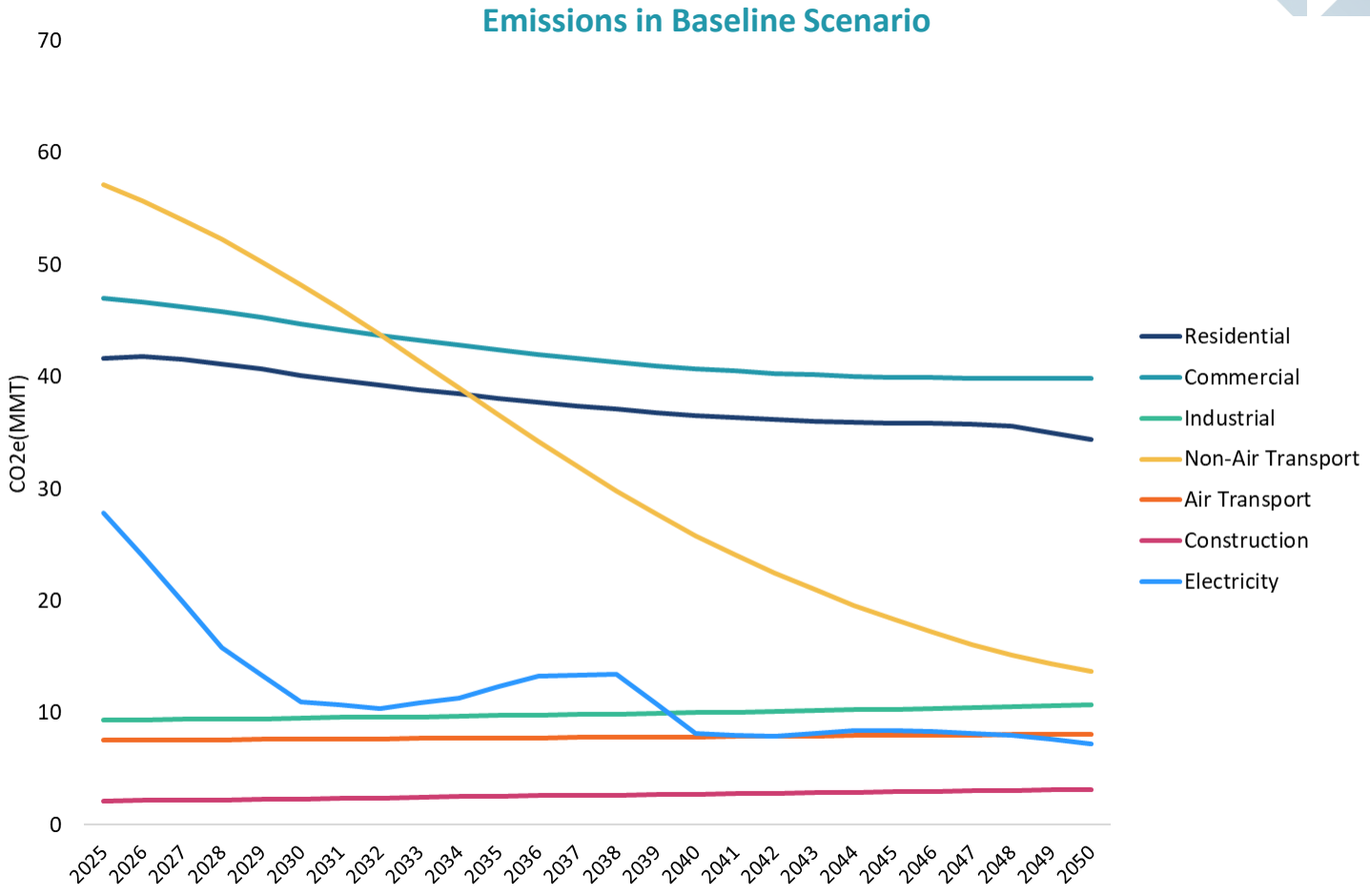



*Note: DEFR penetration is uncertain. In this case, assumptions are aligned with those used by NYISO. Availability of clean imports, lower storage costs, higher zero carbon fuel costs, and effective demand-side management could all reduce the need for DEFR generation.*

# NYCI Scenario Results: Economy-wide

# Economy-Wide Emissions: Reference

- Power sector emissions reflect that the state meets the 70% renewable generation target by 2030, but not the 100% carbon free electricity target by 2040.
- Power sector emissions increase between 2030 and 2038 as load increases, and emissions decrease post 2038 as DEFRs generate at scale.
- New York's industrial sector maintains steady emissions levels due to a combination of both increased energy efficiency and higher output.
- Buildings sectors (residential and commercial) do not experience aggressive abatement – reduces ~15% of emissions from 2025-2050.
- Non-air transport experiences the most decarbonization, achieving around 75% of decarbonization between 2025-2050.

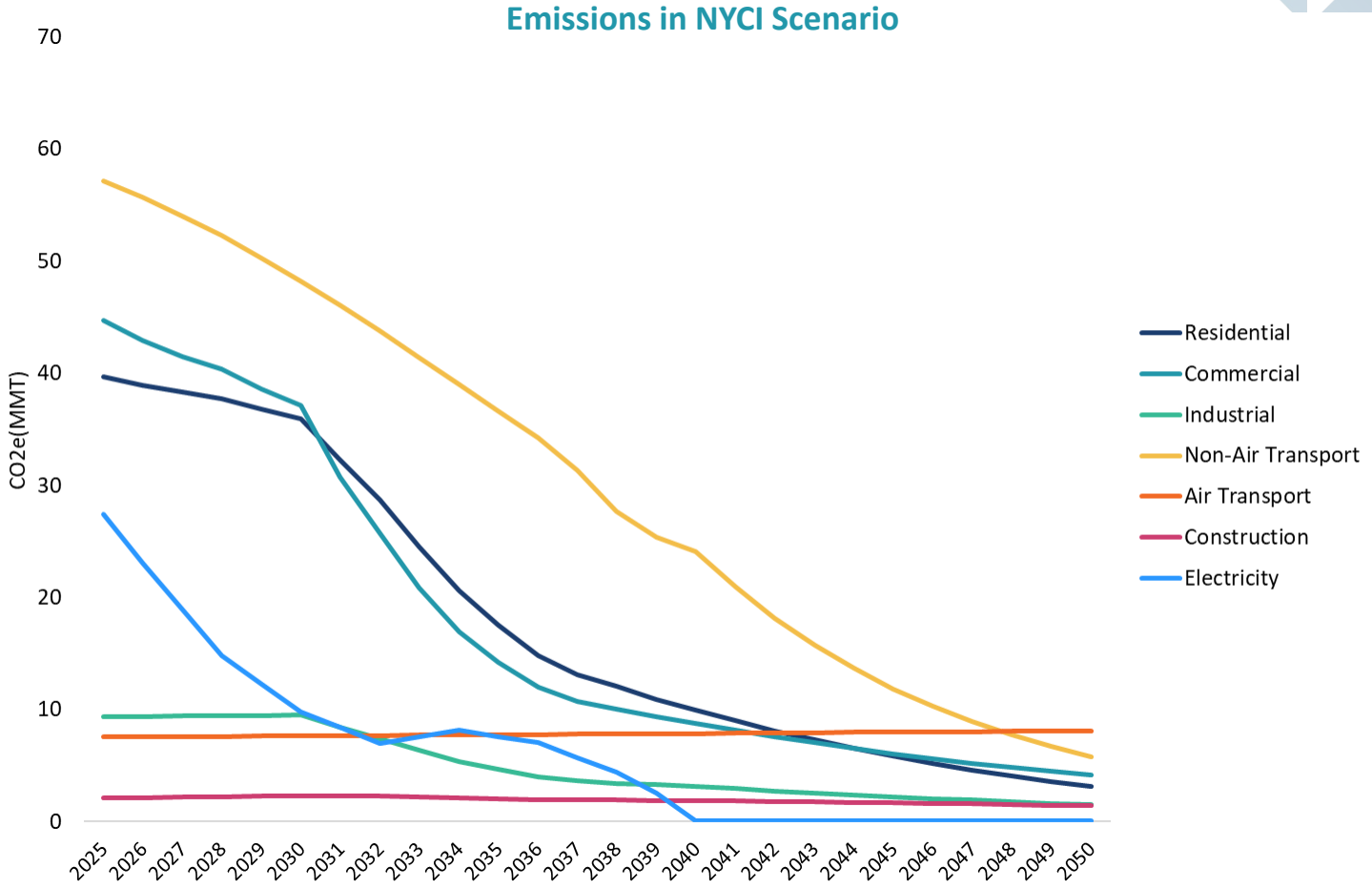



*Reference case assumptions for sectors other than electricity are calibrated to the NYSERDA Integration Analysis 2023 Update*

# Economy-Wide Emissions: NYCI

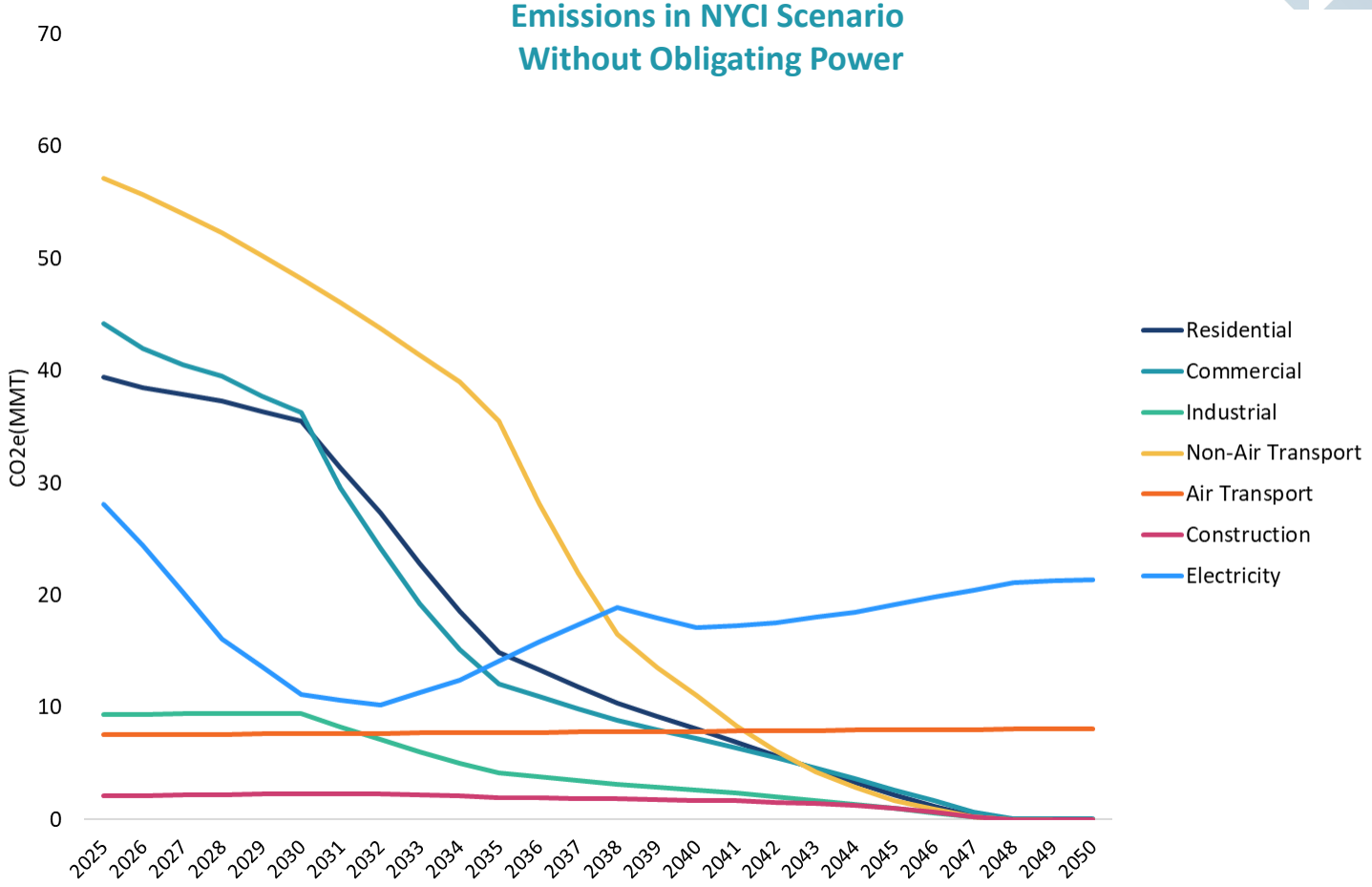
## NYCI drives the power sector to completely decarbonize in 2040.

- NYCI functions as a backstop to achieving the 2040 100% carbon free electricity target.
- Buildings sector (residential and commercial) reduce emissions by more than 90% from 2025-2050.
- Non-air transport further decreases emissions between 2040-2050 compared to the reference scenario, achieving around 90% emissions reduction between 2025-2050.
- New York achieves dramatic reductions in emissions from industrial and construction sectors.
  - Industrial sectors, mainly energy intensive manufacturing (e.g., chemicals industry), reduce total emissions by more than 80%;
  - The construction sector reduces emissions by around 35%.



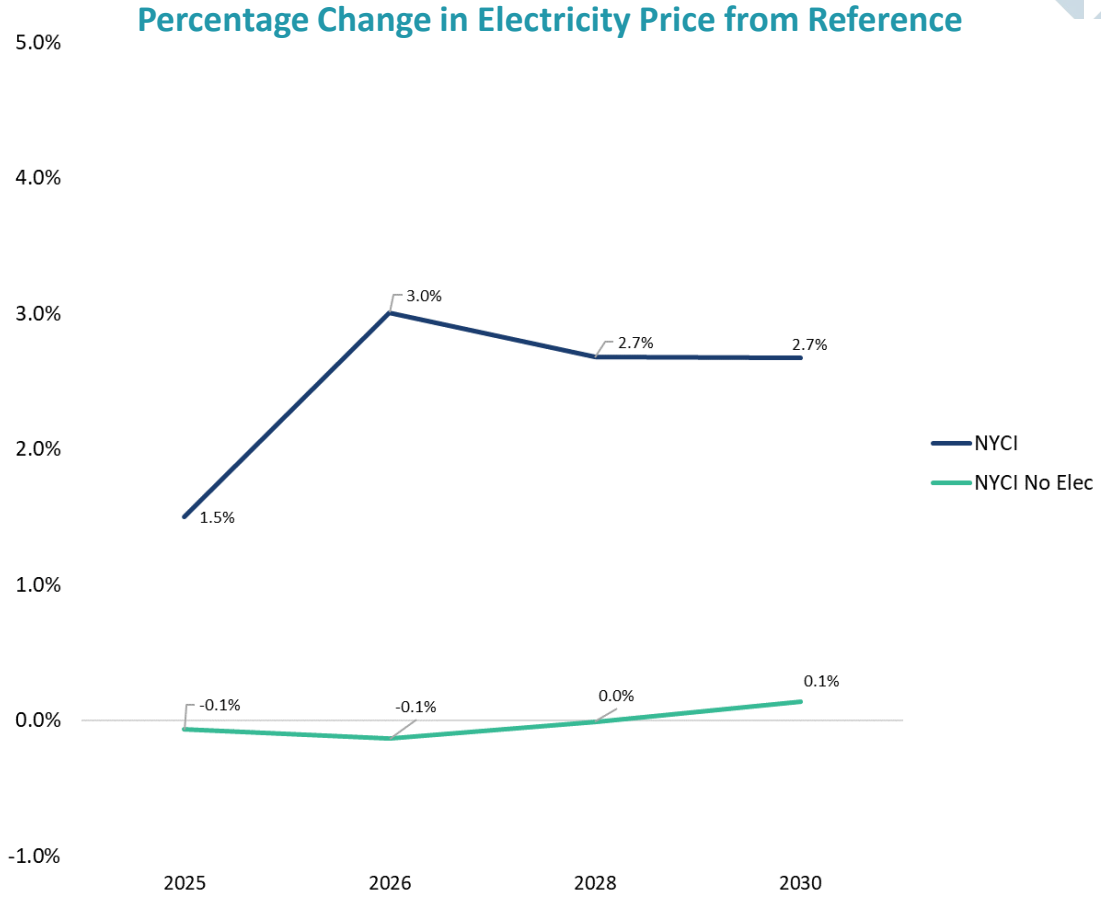
# Economy-Wide Emissions: NYCI w/o Obligating Power Sector

- The rest of the economy is now obligated to decarbonize faster to operate under the NYCI carbon cap, which is achieved by more electrification.
- As a result, when NYCI does not obligate the power sector, the power sector produces substantially more emissions than in the reference case due to higher load requirements.
- Obligated sectors are required to decarbonize completely by 2048, creating significant costs economy-wide.
- Overall, there are slightly more residual emissions in 2050 compared to the standard NYCI scenario.



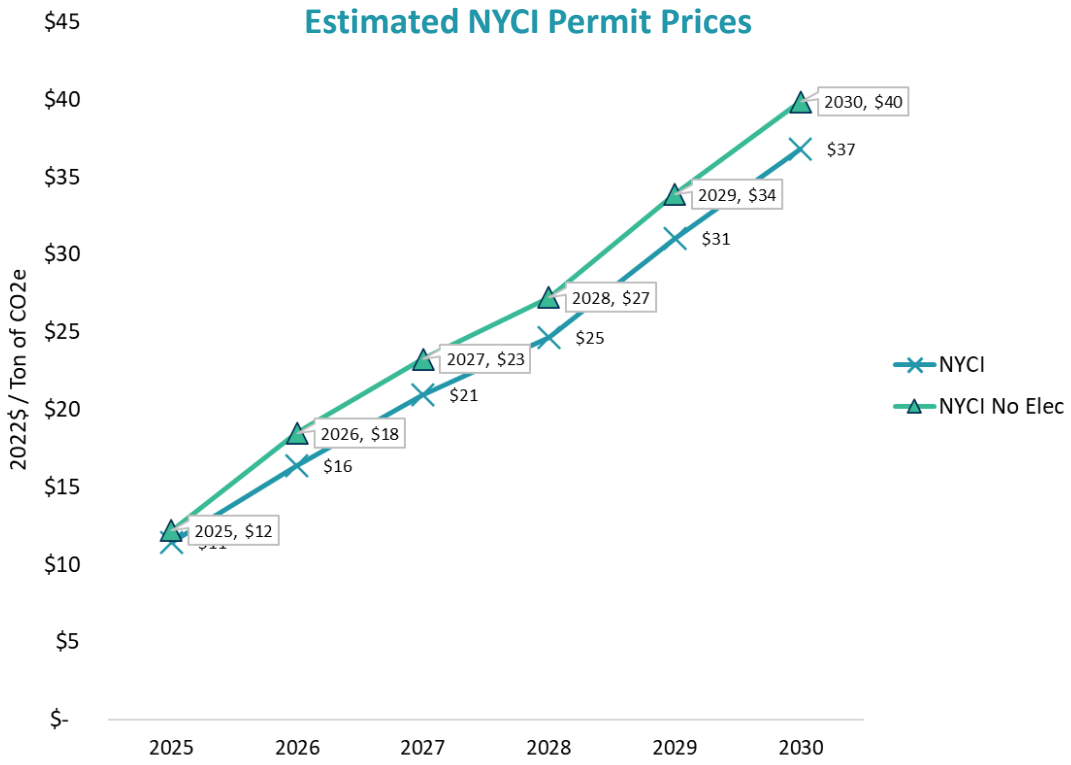
# Retail Electricity Prices

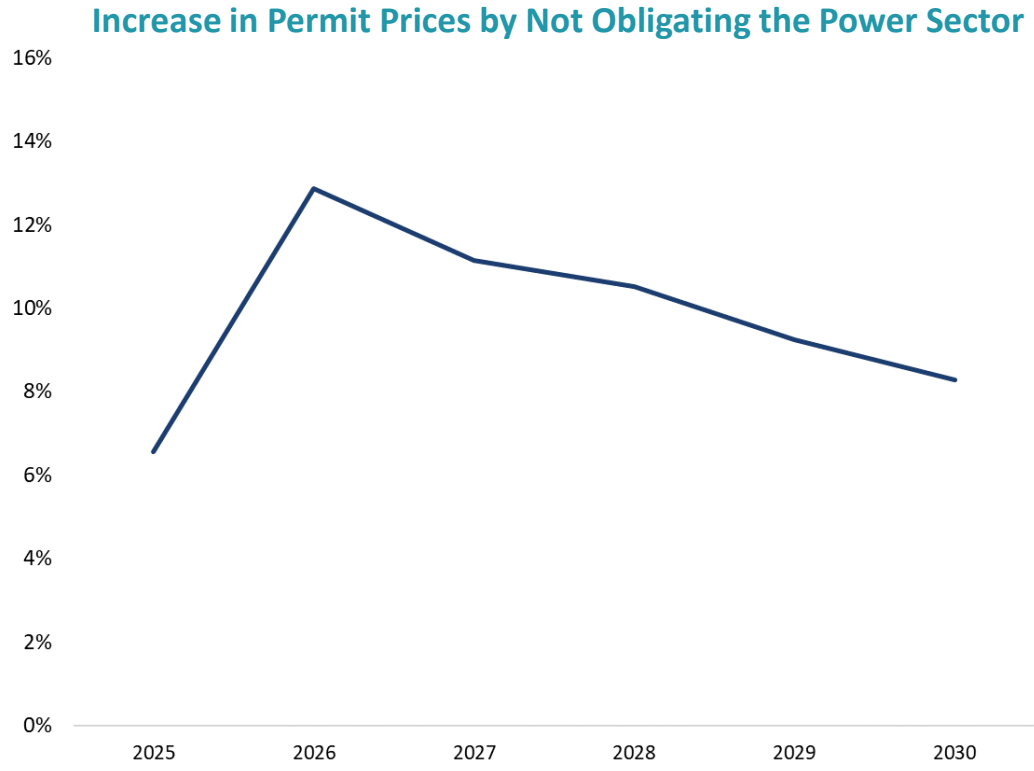
- **Price changes *do not* assume the implementation of strategies to mitigate rate increases, such as:**
  - Redistribution of NYCI permit revenue to consumers, which is required under the NYCI program;
  - Other policy mechanisms available to offset any ratepayer costs (e.g., no-cost permit allocation to electric distribution utilities for the benefit of their customers).
- Changes to retail electricity prices are estimated from simulated changes in wholesale prices.
- In general, electricity rates are higher than in the reference scenario between 2025-2030 due to:
  - Increased demand for electricity
  - NYCI permit price applied to fossil-based generation (when electricity is obligated)
  - Higher system costs driven by decarbonization



# NYCI Emissions Permit Prices

Not obligating the power sector increases the permit price, as the transportation and buildings sectors abate emissions more aggressively, increasing marginal abatement costs.




Note: in-year permit prices estimates may diverge from other modeling of the NYCI program including by NYSERDA (Jan 2024) as:

- Permit banking is not modeled
- Unlike partial equilibrium models that only consider the supply-side costs of emissions abatement, general equilibrium models account for economy-wide ripple effects that also consider the demand-side costs associated with higher commodity prices and reduced demand.

# Impact of NYCI on Real GDP in New York

GDP continues to grow considerably under NYCI, at a rate comparable to the rate of growth under the reference scenario. The modeled decrease in annual GDP growth on average is estimated to be *less than a tenth of a percent* (< 0.1% ) relative to the rate of growth under the reference case.