Specificity in System Planning

Considering Regional Attributes in a Power System Model

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Project Motivation

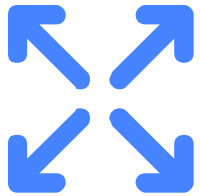
This project explores how specific constraint design and distributional impacts analysis are enabled by using a nodal capacity expansion model.

Specific Constraint Design

- Utilizing a nodal model allows for focused candidate generation selection and constraint, to examine specific decarbonization pathways in comparison to each other

Distributional Impacts Analysis

- Mapping out optimal systems allows for the assessment of who might be impacted by these systems, especially with respect to air quality



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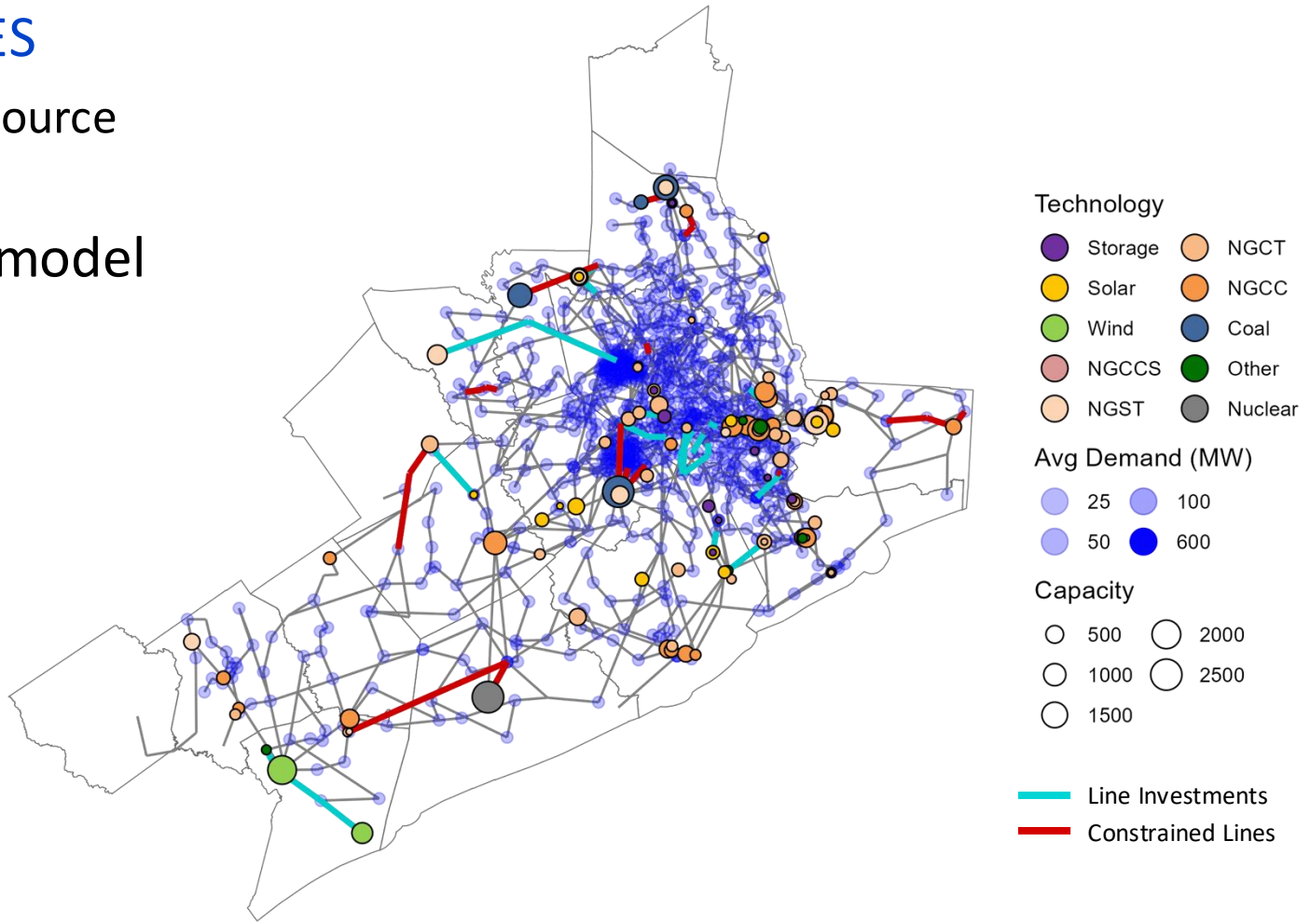
Model Overview

- Modeling Implemented in EPRI-TEPES
  - In-house model derived from the open source Open-TEPES model
- Linear / Mixed Integer optimization model
  - Unit-level investment and dispatch
  - Includes network investment
  - Unit commitment economic dispatch
  - Includes DC power flow equations
- Allows for high level of spatial and temporal granularity
  - 957 Nodes and 1393 lines
  - 72 active and 156 candidate generators
  - 1092 segments (13 weeks, 2-hour intervals)



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Scenarios

- All scenarios are based in 2030
- Three decarbonization levels, which allow the model to achieve these levels with all technology options
- Retire/retrofit constraint requires scenarios to retire the highest emitting coal plants
- Final scenarios are the most cost-effective options at each decarbonization level
- Retrofitting and retiring specified coal plants is more cost-effective after 20% decarbonization

Scenario Name	Description	Retire / Retrofit
Reference	2030 case with no constraints	No
Coal Retrofit	Retrofit large coal plants to natural gas	**Yes**
10% Decarbonization	10% CO_2 reduction relative to 2030 reference	No
25% Decarbonization	25% CO_2 reduction relative to 2030 reference	**Yes**
50% Decarbonization	50% CO_2 reduction relative to 2030 reference	**Yes**

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Model Results

Aggregate Picture

- System-wide results demonstrate how capacity, generation, and air quality change in each scenario
- These results represent a standard set of results from a zonal capacity expansion model

Local Implications

- Maps of optimal locations for **synthetic** power system assets in each scenario
- Illustrates how the aggregate results might look in practice
- Overlaid with approximate representations of air quality impacts, and vulnerable census tracts
- Deeper insight into distributional impacts of each scenario

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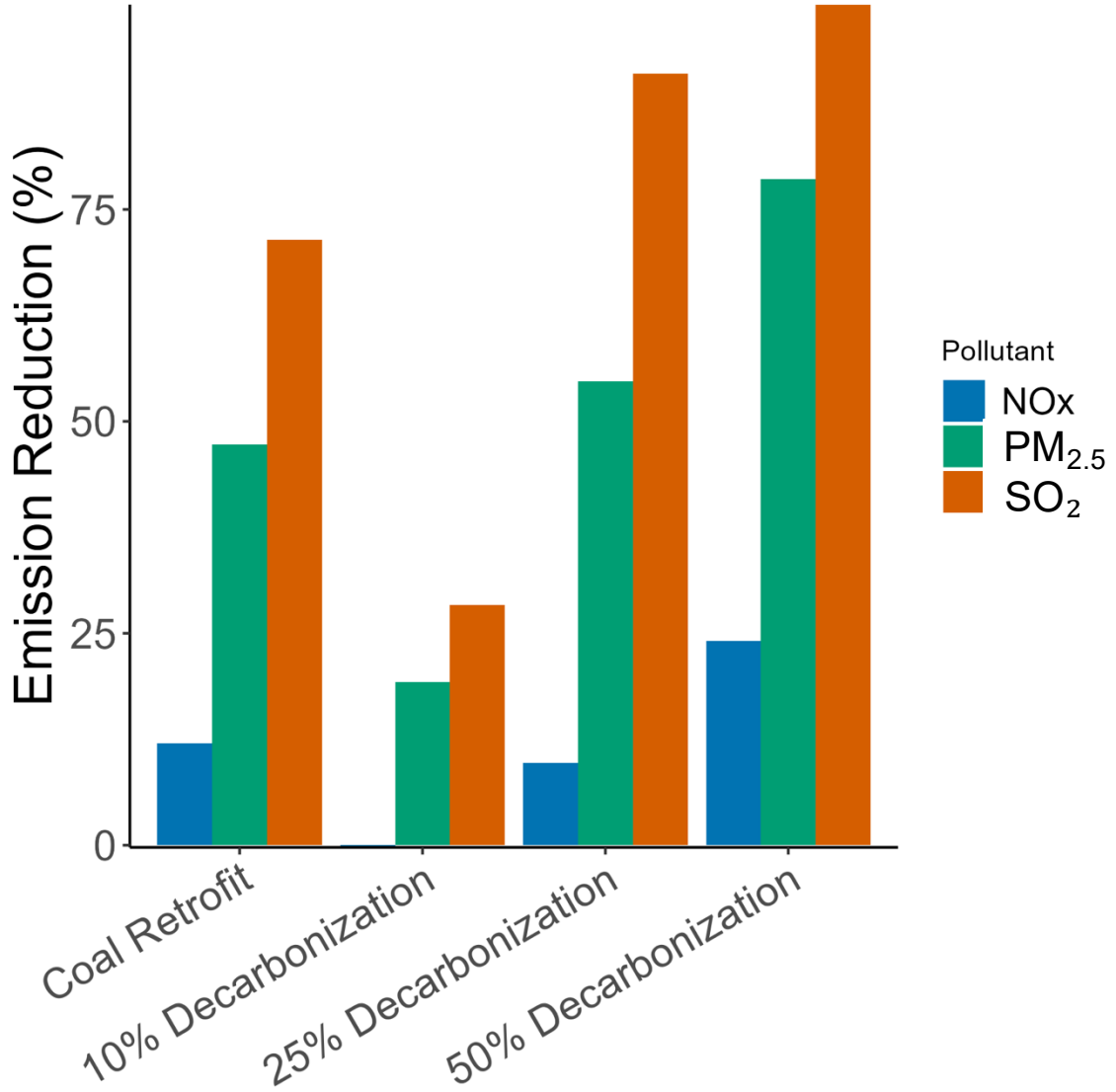
Aggregate Results: Emissions

- Coal Retirement/Retrofit results in a sharp decline in SO_2 emissions, which start out as the most prevalent pollutant, and drop off almost completely by 50% decarbonization
- Primary $PM_{2.5}$ declines slowly across all scenarios
- NOx reductions are relatively modest compared to the other pollutants



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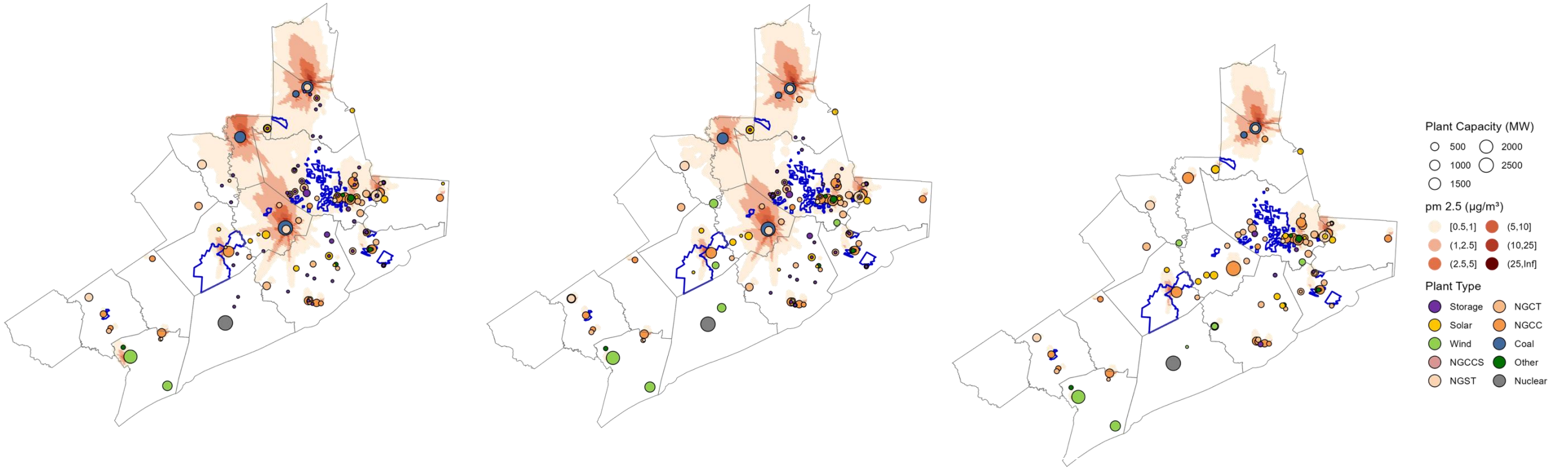
Local Implications – Primary $PM_{2.5}$ Results

Reference

10% Decarbonization

25% Decarbonization



Note: This is a modeled, synthetic test system, and is not intended to represent real assets or their operations.

Utilizing a nodal capacity expansion model coupled with approximate air quality projections can create insights about how the impacts of decarbonization are being distributed.

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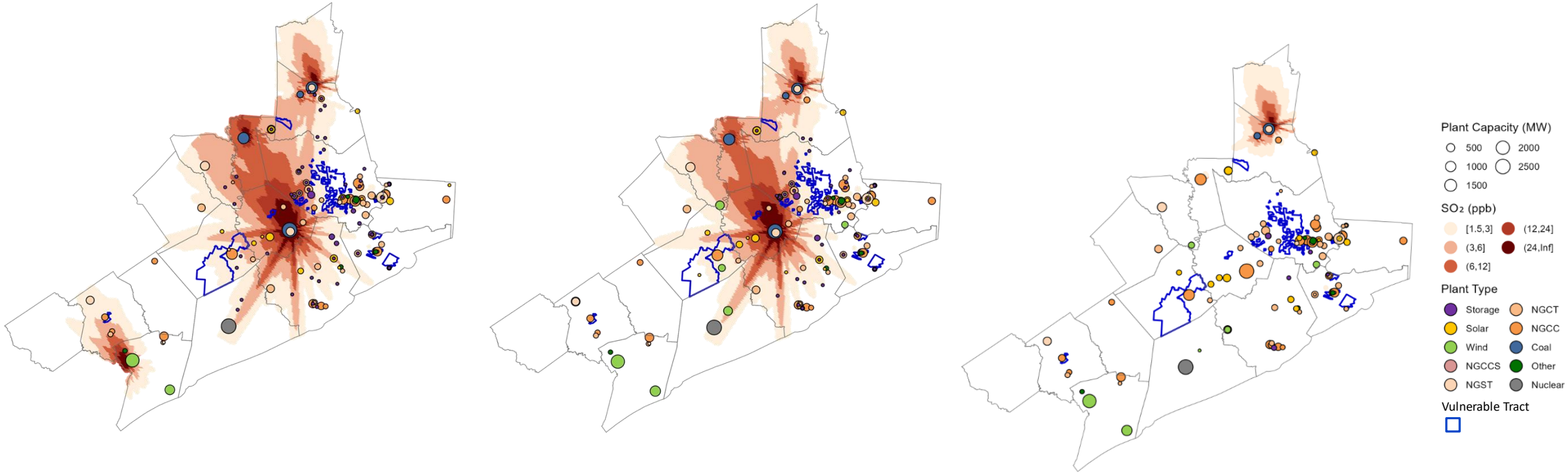
Local Implications – SO_2 Results

Reference

10% Decarbonization

25% Decarbonization



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Retiring and retrofitting the three largest coal plants reduces most primary $PM_{2.5}$ and SO_2 emissions from the system.

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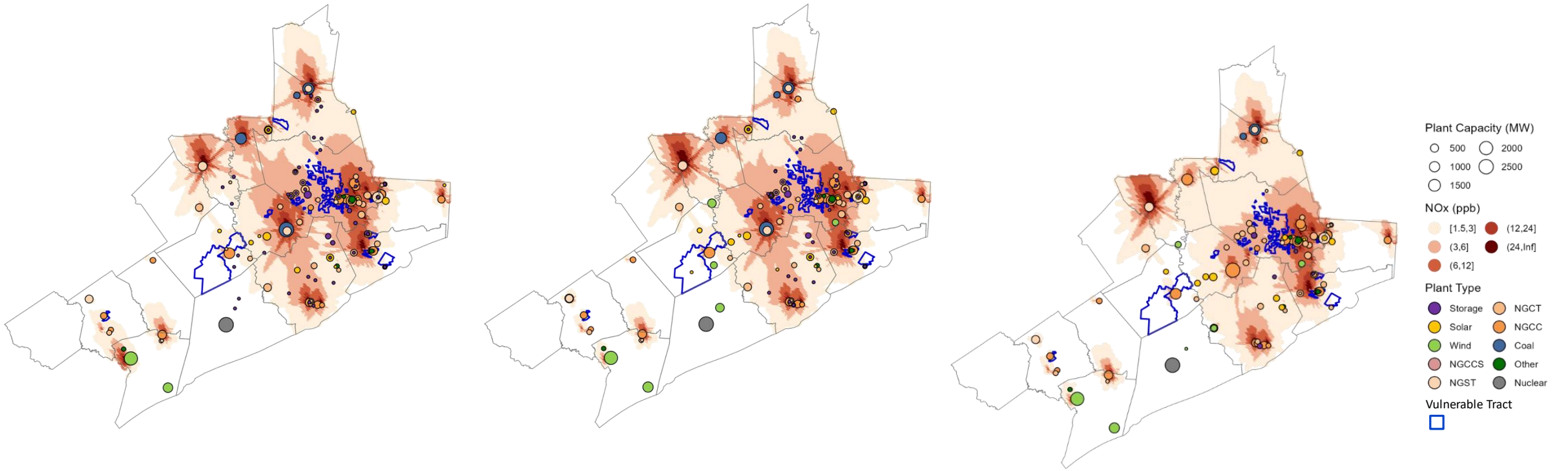
Local Implications – NOx Results

Reference

10% Decarbonization

25% Decarbonization



Note: This is a modeled, synthetic test system, and is not intended to represent real assets or their operations.

NOx emissions vary less by fuel type and more by plant-specific characteristics, compared with CO_2, PM2.5, and SO_2.

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Key Takeaways

- Utilizing a nodal capacity expansion model coupled with approximate air quality projections can create insights about how the impacts of decarbonization are being distributed.
- For this system, the primary decarbonization strategy is retrofitting coal plants to natural gas, which can result in lingering NOx concentrations in vulnerable regions, which are located near a cluster of natural gas plants that are used to meet peak load.
- These power system assets are synthetic, but this a demonstration of how this type of analysis can provide information about how different decarbonization strategies may result in different impacts and a different distribution of those impacts.

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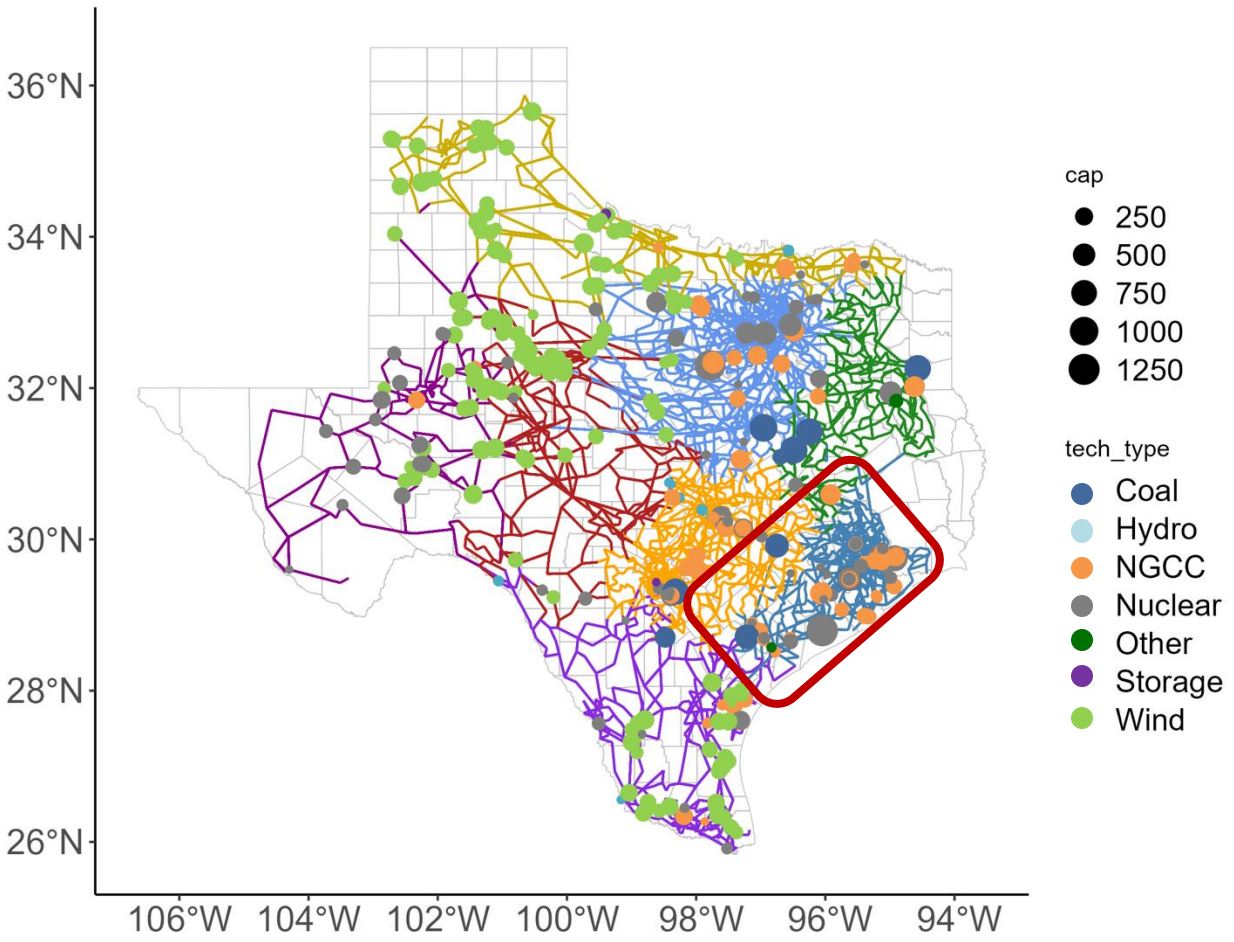
Appendix

Test System Description

- Start with Texas A&M synthetic test system[2]
  - Transmission and generation model of the Texas grid for 2021
  - Subset to Houston region network and nearby generators
- Project to 2030
  - Use ERCOT demand growth projections to scale substation demand (88% increase)
  - Retire plants scheduled to retire by 2030
  - Add candidate generators based on planned additions and constrained nodes
- Supplement with additional information
  - Generator emissions from EPA[3]
  - Investment costs from EPRI reports



Granular test system with realistic network, generation, and investment

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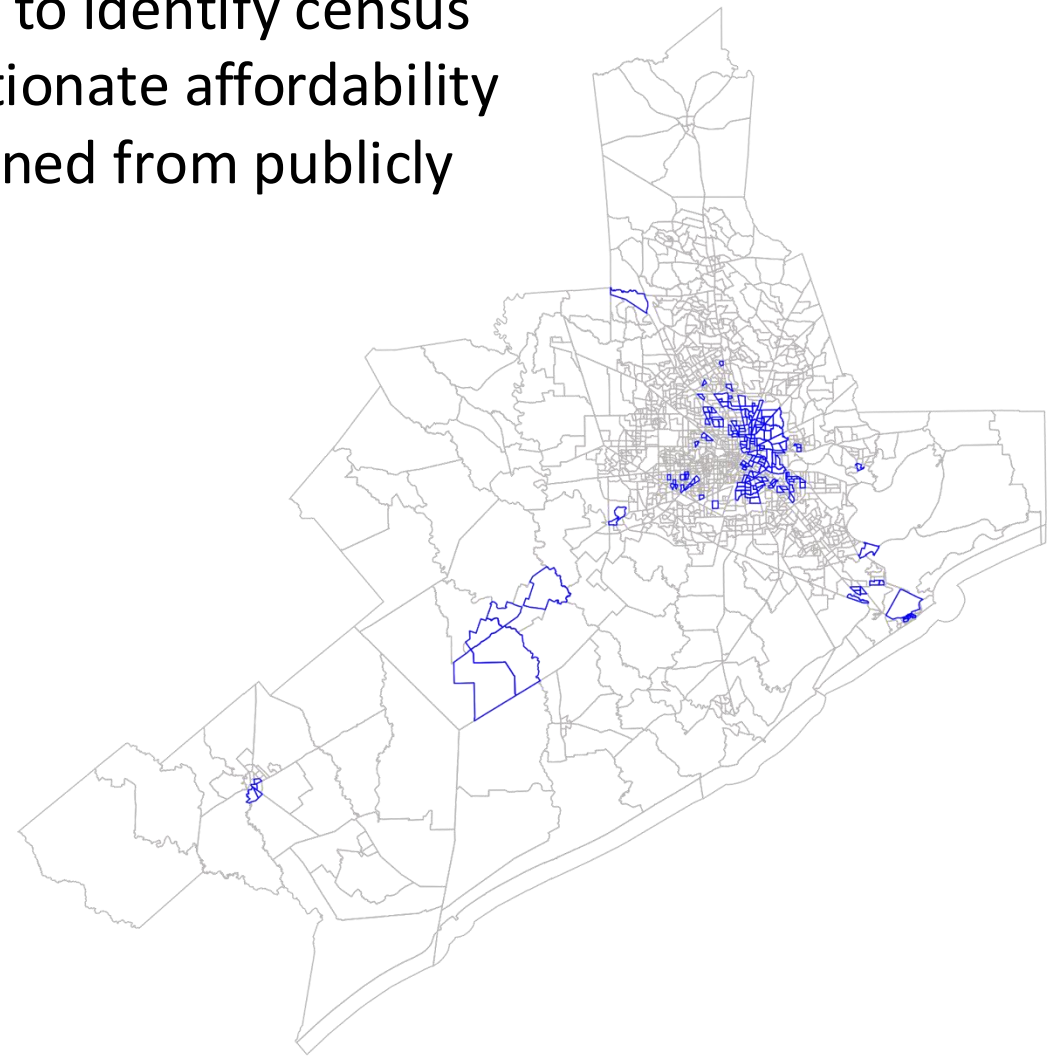
Vulnerability Metrics Overview and Visualization

Vulnerability indicators were selected to identify census tracts that may experience disproportionate affordability or health impacts. Metrics were obtained from publicly available datasets[4,5].

Selected Metrics
Income
Energy Burden
Unemployment
$PM_{2.5}$ Concentration
Ozone concentration
Asthma incidence in adults
Heart Disease incidence in adults
Diabetes incidence in adults



Vulnerable Tract

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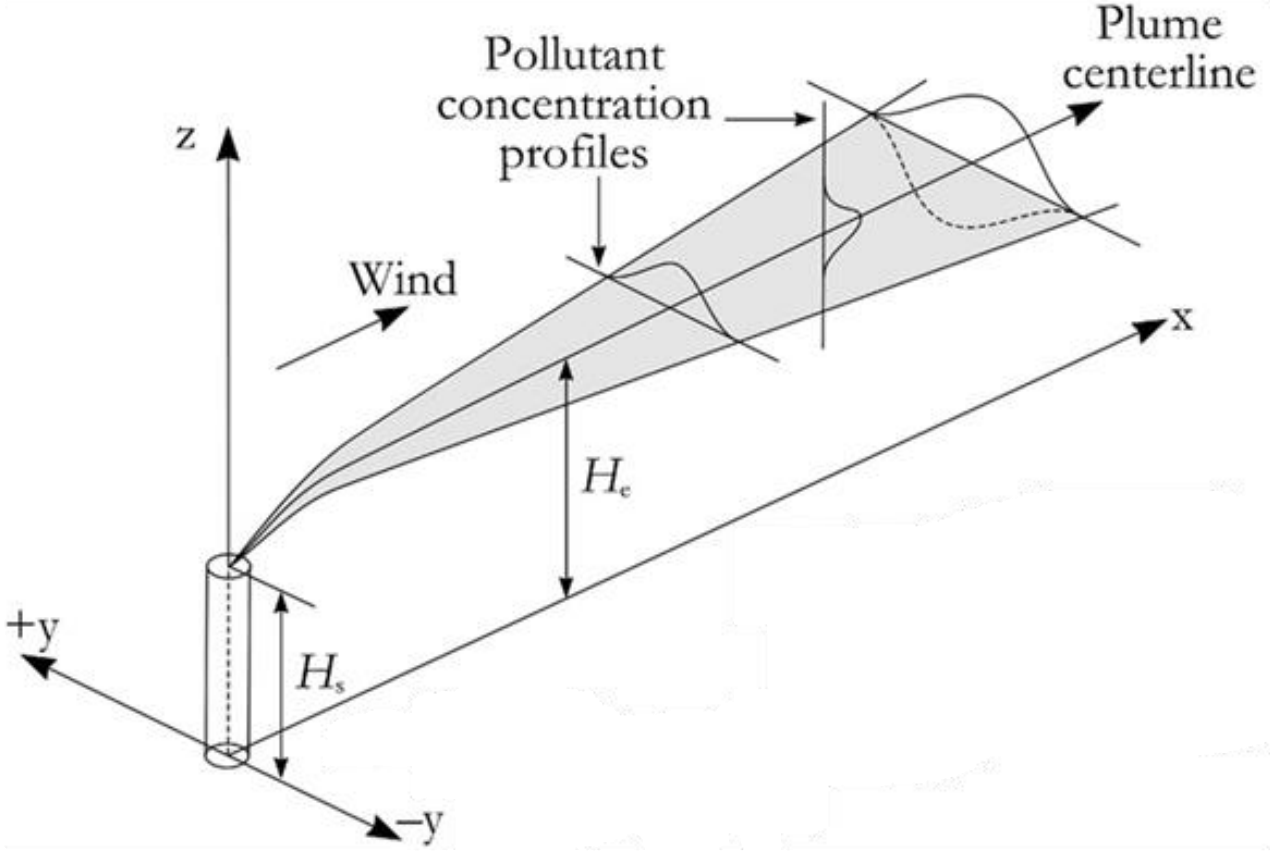
Representation of Air Quality Impacts



- We use a simplified **Gaussian Plume model** as a simple representation of the potential dispersion of criteria pollutants from point-sources.
  - This approach is similar to the EPA's AERMOD Modeling system[6], and does not model atmospheric chemistry impacts on pollutant concentrations.
- This allows us to **convert plant emissions to annual average estimates of pollutant concentrations**, and subsequent impacts on nearby populations.
- Enables a deeper understanding of the impacts of different decarbonization pathways and asset-specific decisions.

Pollutant Concentrations Depend On:

- Wind speed and direction
- Height of smokestack and height of downwind area affected
- Distance and position from emission source
- Parameters affecting emission dispersion

Pollutant Concentrations DO NOT Depend On:

- Atmospheric chemistry
- This study only includes analysis of primary $PM_{2.5}$, NOx, and SO_2 emitted from point sources

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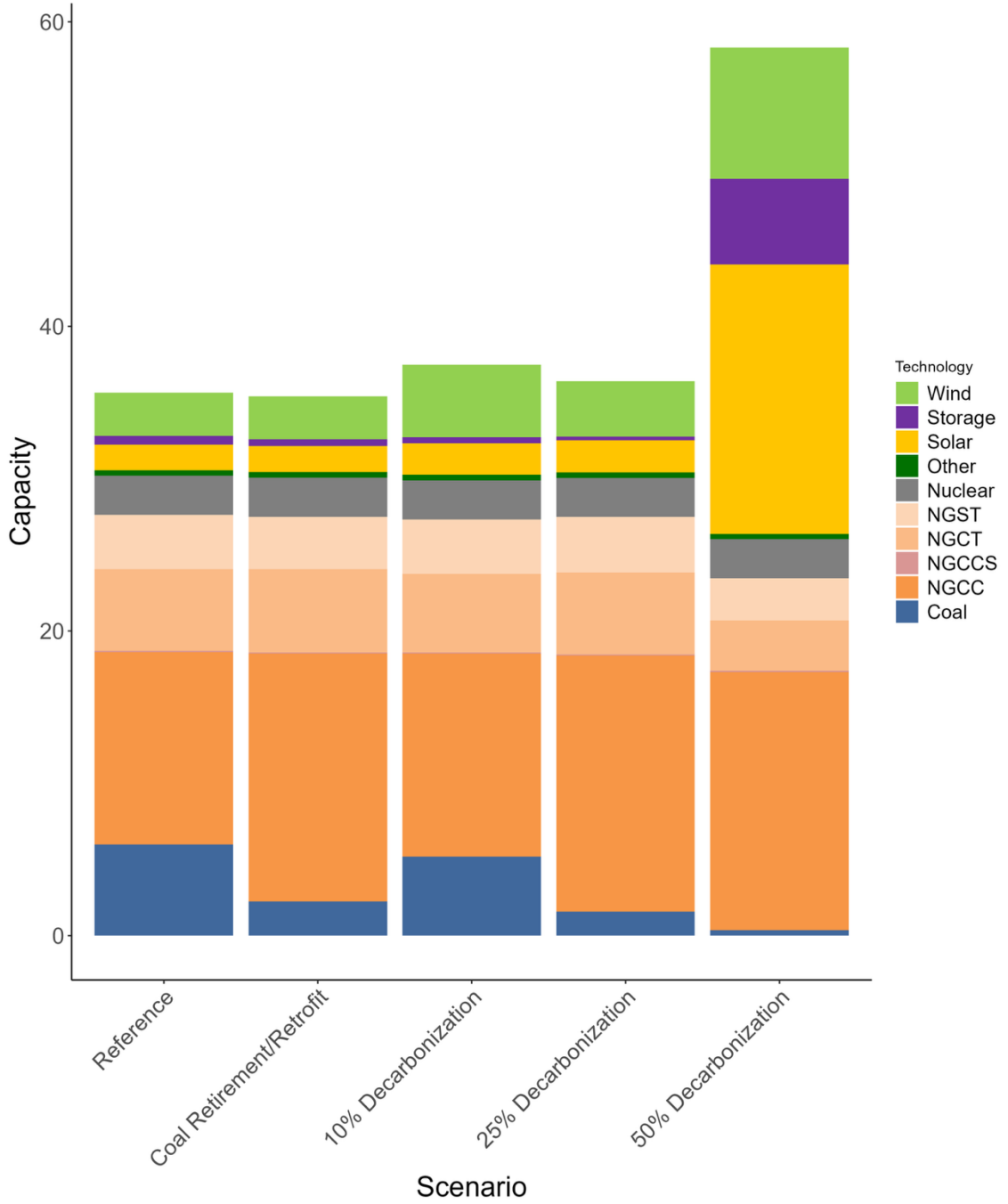
Aggregate Results: Capacity

- Decarbonizing 10% keeps reference-level capacity with the addition of wind.
- Retrofitting to gas reduces wind buildout in decarbonization scenarios.
- Decarbonizing 25% keeps reference-level capacity, and retrofits some coal capacity to natural gas
- 50% reductions results in the most major changes, including retiring most coal capacity, reducing natural as capacity across all types, and large solar, storage, and wind additions.



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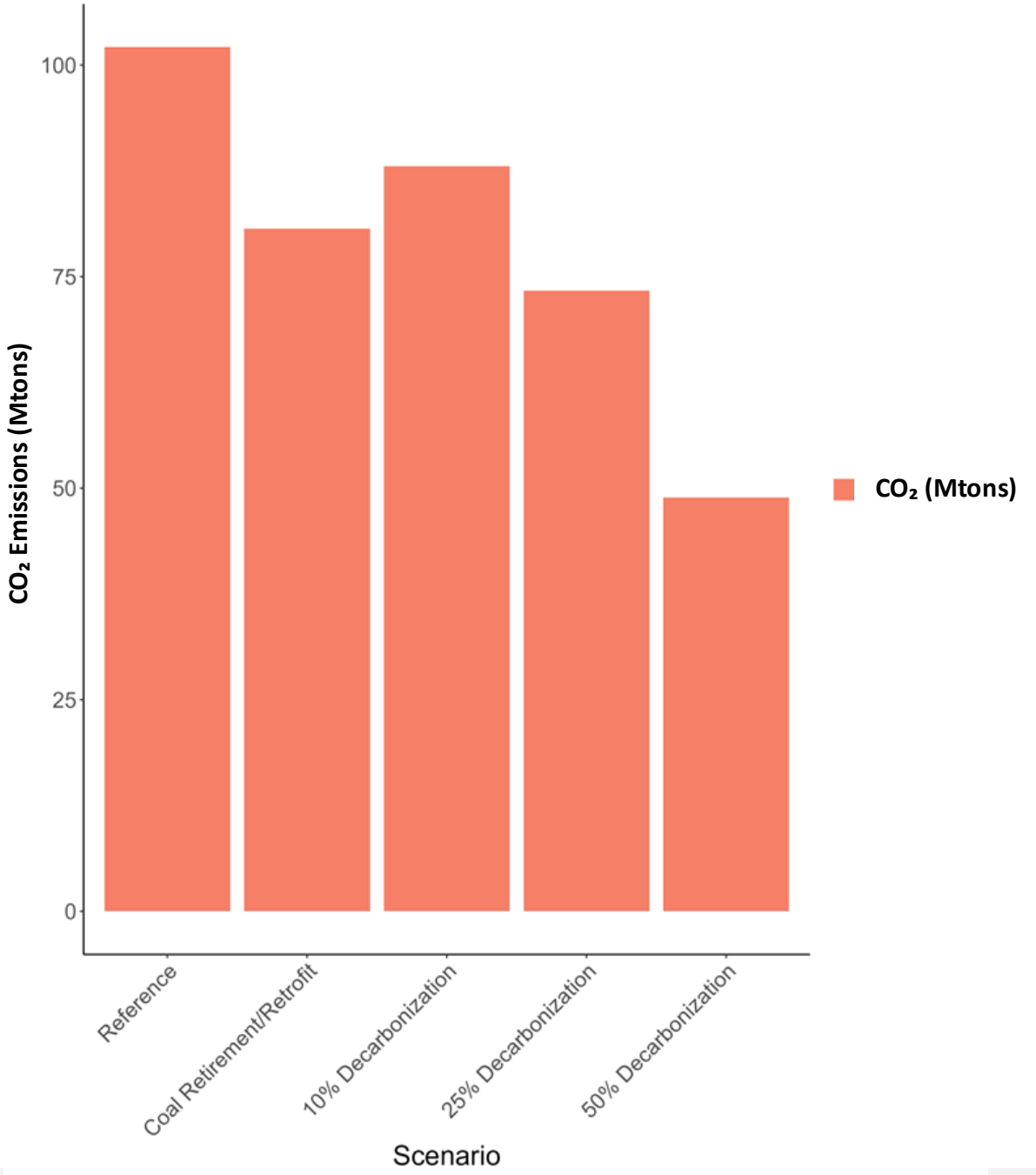
Aggregate Results: Emissions

- CO_2 emissions in the last three scenarios are specified by the scenario design
- Retiring/retrofitting large coal plants outside of a specified decarbonization level reduces CO_2 emissions by 21%



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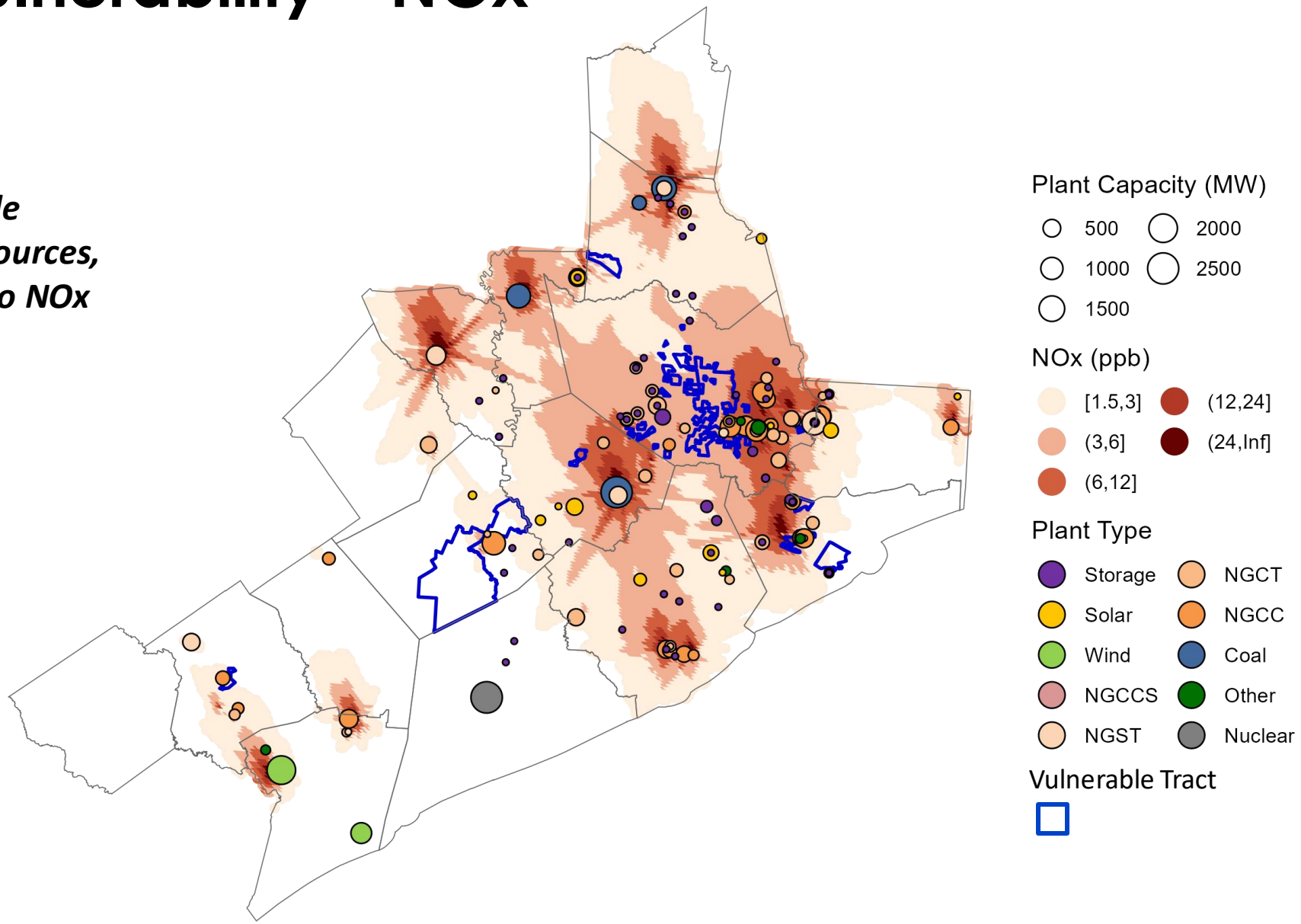
Air Quality and Vulnerability – NOx

Reference

Note: The following slides only include analysis of NOx emitted from point sources, and do not explicitly model impacts to NOx concentrations that emerge from atmospheric chemistry processes.



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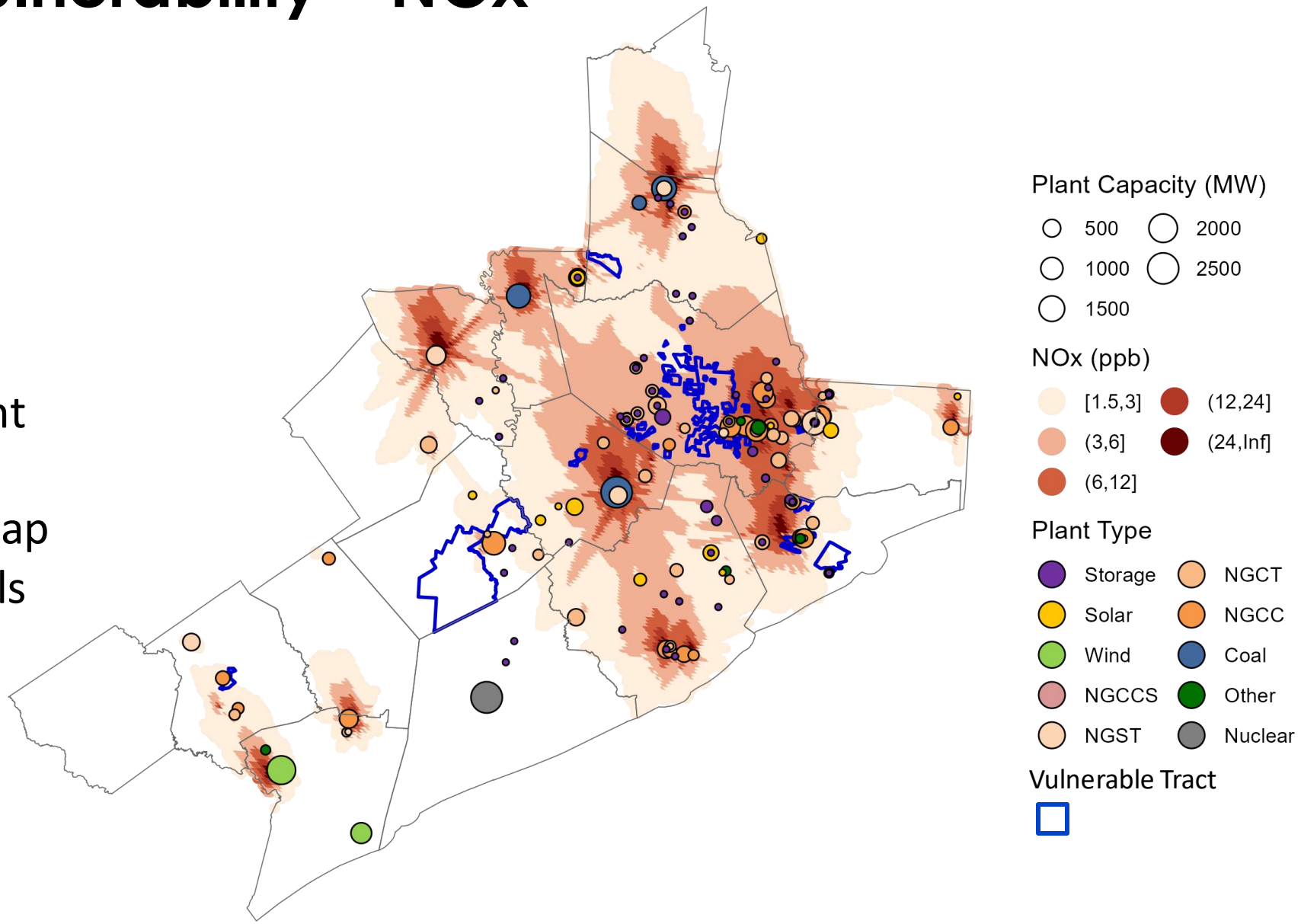
Air Quality and Vulnerability – NOx

Reference

- Both natural gas and coal plants can contribute significantly to NOx concentrations.
- NOx emissions vary by plant characteristics.
- There is considerable overlap of regions with higher levels of NOx concentrations and vulnerable census tracts.



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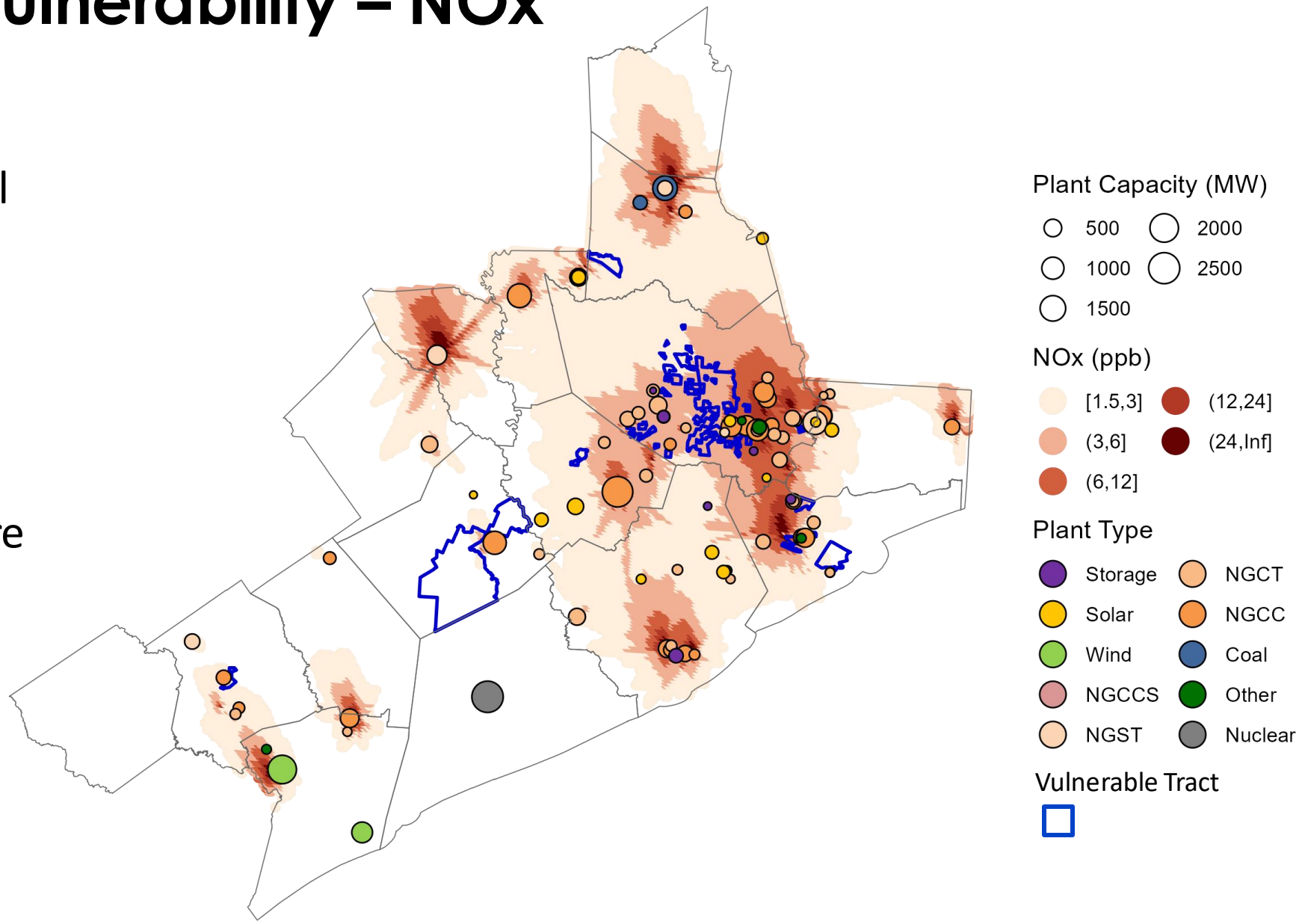
Air Quality and Vulnerability – NOx

Coal Retirement/Retrofit

- Retrofitting two large coal plants results in a decrease in NOx concentrations in the areas surrounding those plants.
- Some vulnerable tracts are located in areas where NOx concentrations decrease significantly, though remaining NOx concentrations are still relatively high in many of these areas.



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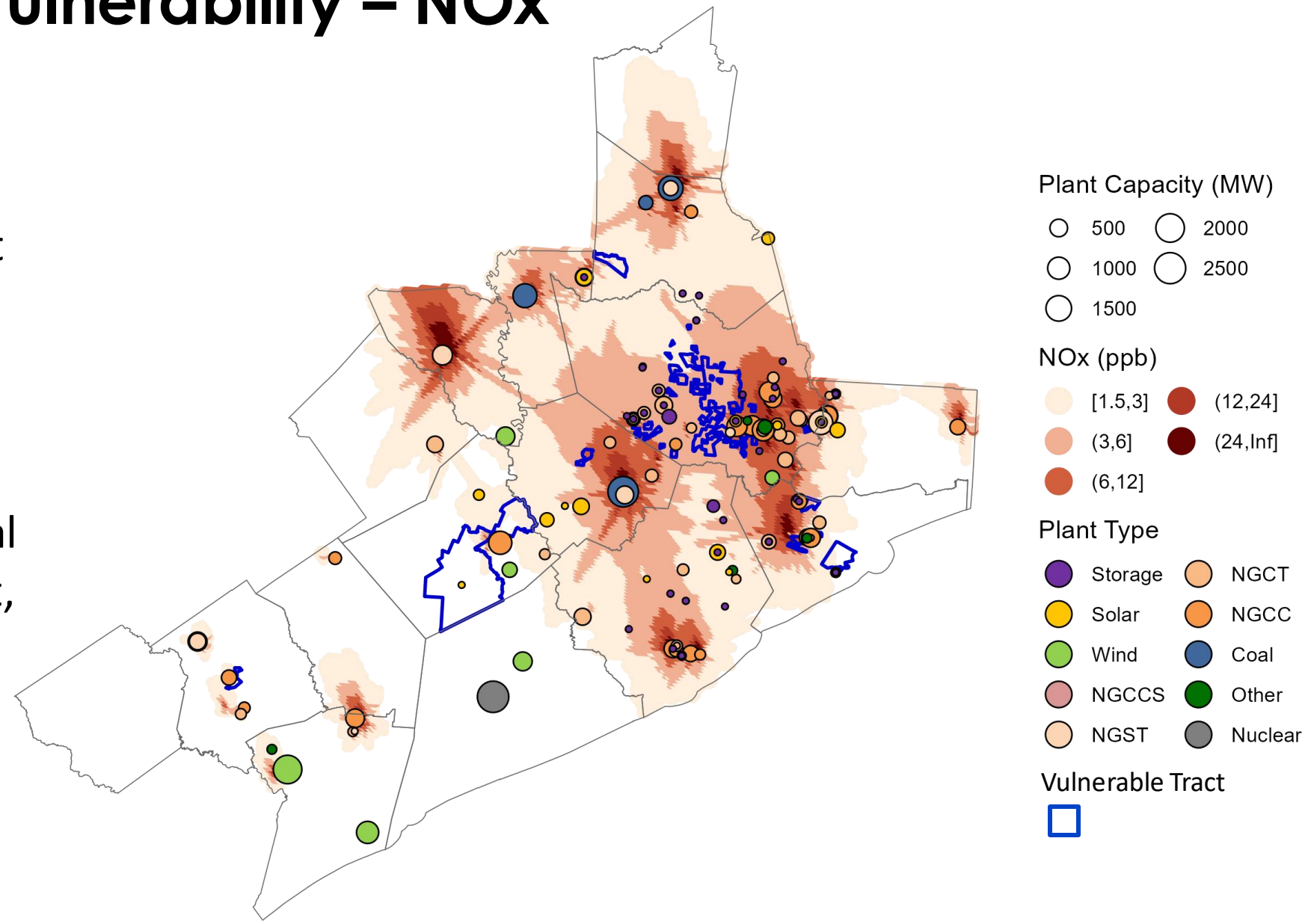
Air Quality and Vulnerability – NOx

10% Decarbonization

- Achieving 10% decarbonization does not change NOx concentrations in most areas.
- This scenario does not require the retrofit of coal plants to reach the target, and in some places NOx concentrations actually increase.



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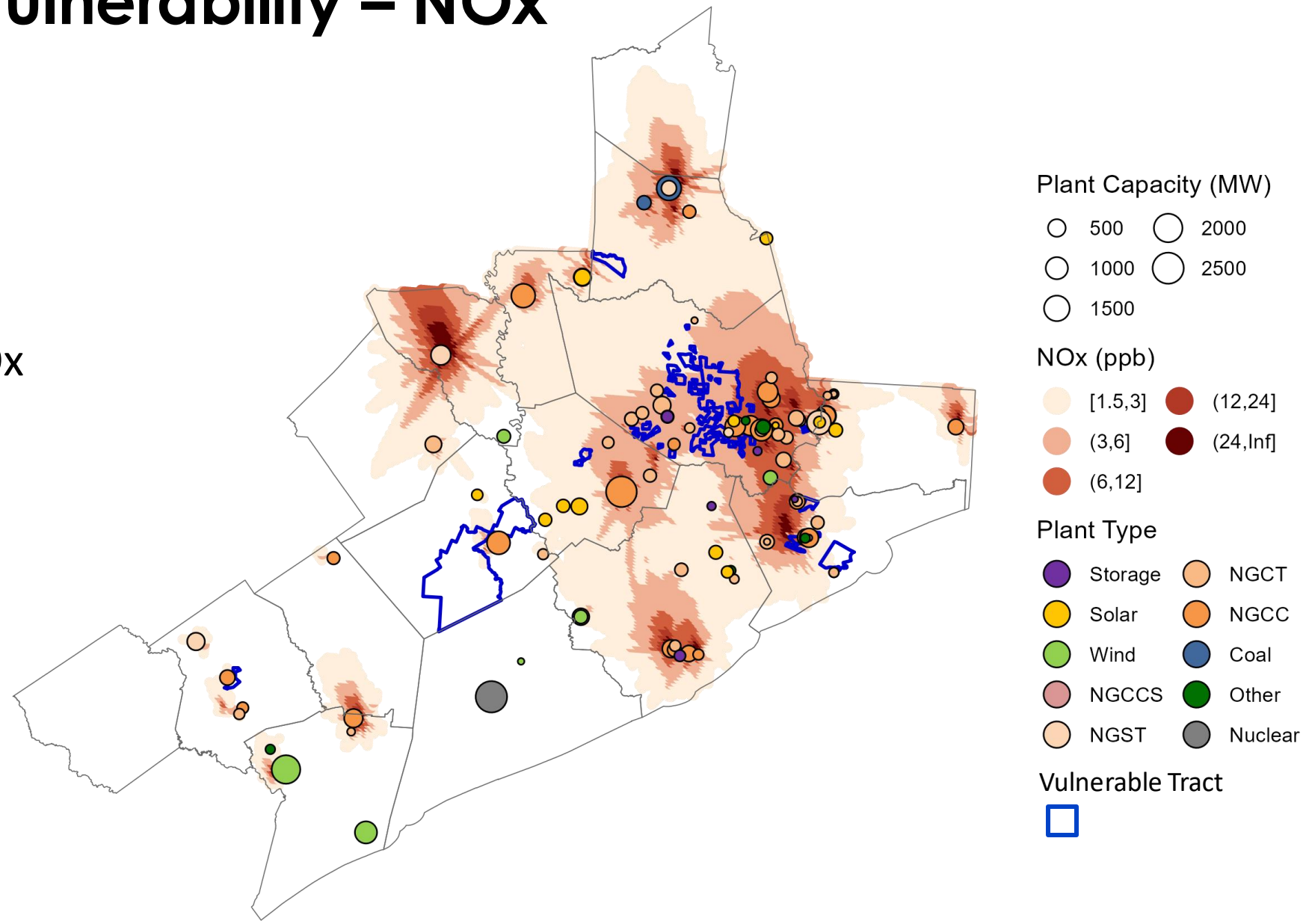
Air Quality and Vulnerability – NOx

25% Decarbonization

- Reaching 25% decarbonization includes retrofitting major coal plants, which reduces NOx concentrations.
- Vulnerable areas see limited decrease in NOx concentrations.



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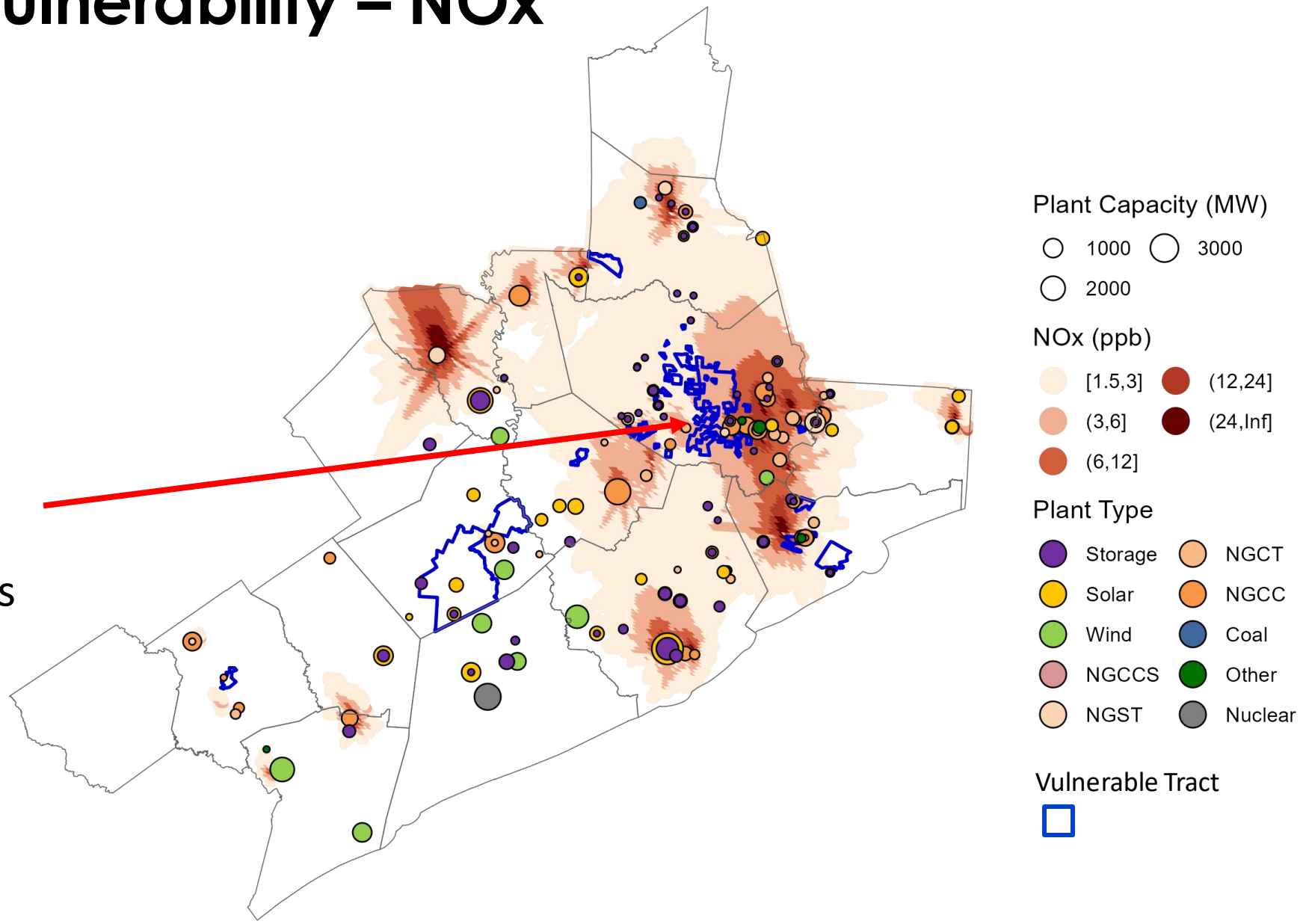
Air Quality and Vulnerability – NOx

50% Decarbonization

- NOx concentrations decrease further as the system achieves 50% decarbonization, due to increased presence of wind and battery storage.
- Areas where natural gas plants are used as peakers still see relatively high NOx concentrations.
- These specific natural gas plants are located near many vulnerable census tracts.



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NOx Conclusions

- NOx emissions vary less by fuel type and more by plant-specific characteristics, compared with CO_2, $PM_{2.5}$, and SO_2.
  - For example, NOx emissions from natural gas plants can range very widely. Some natural gas plants have a higher NOx emission rate than coal plants in this system.
- Initial progress on decarbonization trajectories reduces NOx concentrations around both coal and natural gas plants.
- To meet demand after retrofitting large coal plants, natural gas plants clustered near most of the vulnerable census tracts in this region are used to meet peak load.
- Ramping these plants results in persistent NOx concentrations near most designated vulnerable census tracts. This finding may be driven primarily by regional factors and may not be generalizable to other areas.

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