College of Engineering – Center for Environmental Research and Technology

Air Quality and Health Implications of Emerging Trends in Freight Logistics

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From Air Pollution Sources to Health Impacts

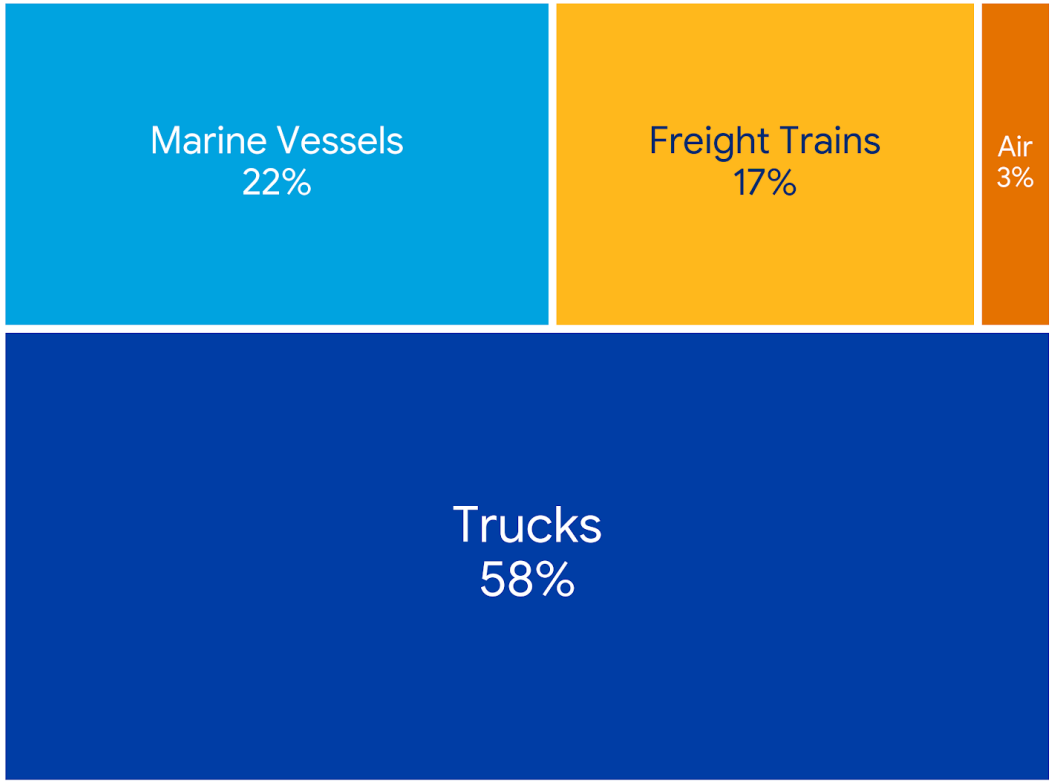
Source: Center for Advancing Research in Transportation Emissions, Energy and Health

Air Quality and Health Impacts of Freight Logistics

- Freight transportation primarily involves the use diesel engines.
  - Road → Trucks
  - Rail → Freight trains
  - Water → Marine vessels

- Diesel emissions can adversely impact air quality and health.
  - Nitrogen oxides (NOx)
  - Particulate matter (PM)
  - Air toxics

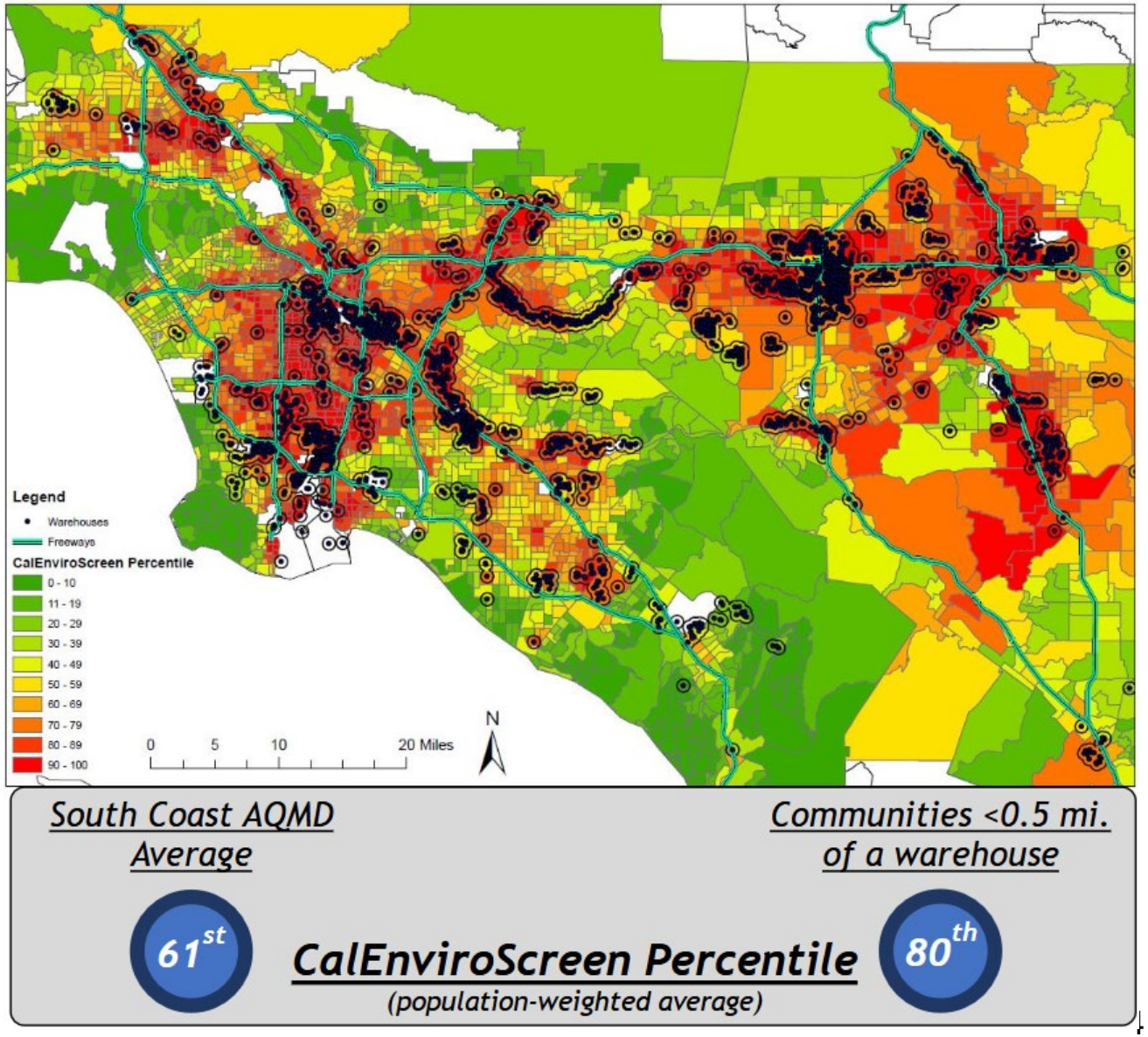
Share of NOx Emissions by Freight Transportation Mode (2020)



Source: U.S. Environmental Protection Agency, 2020 National Emissions Inventory

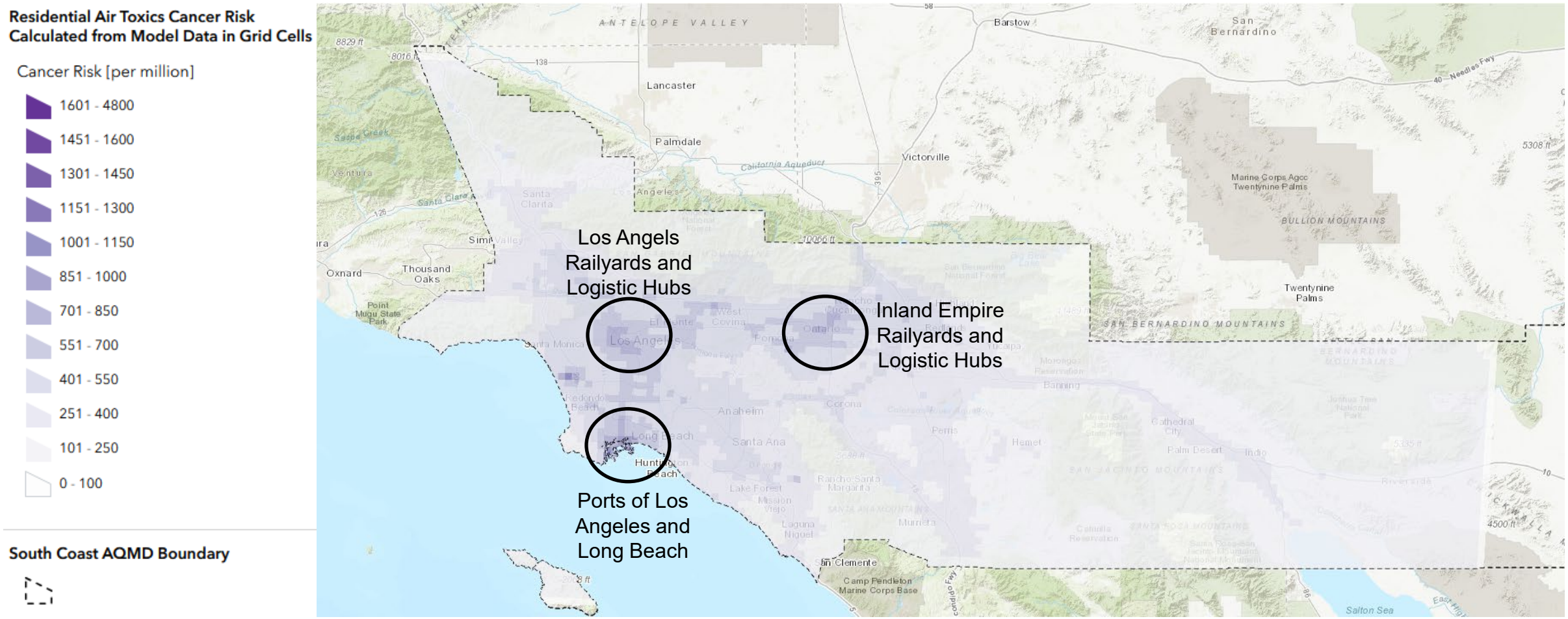
Concentrated Diesel Emissions

- Can occur at freight hubs and along freight corridors
  - Intermodal facilities such as seaports & railyards
  - Warehouses and distribution centers
  - Freeways and major arterials



Source: South Coast Air Quality Management District. Proposed Rule 2305 – Warehouse Indirect Source Rule (2021)

Estimated Cancer Risk in South Coast Air Basin, California



Source: South Coast Air Quality Management District, MATE V Study (2018)

Emerging Trends in Freight Logistics

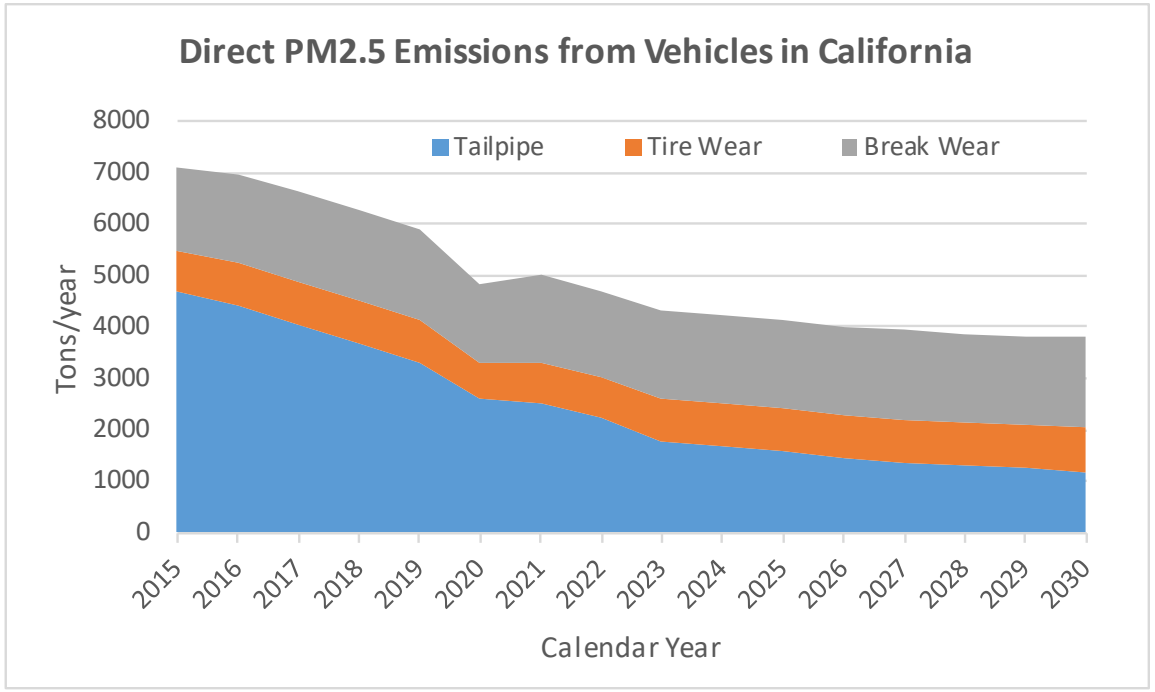
- Urbanization of freight hubs
  - Moving from regional hubs outside cities to micro hubs inside urban centers.
- Increasing importance of non-exhaust emissions
  - As tailpipes get cleaner, brakes and tires become dominant sources of traffic emissions.
- Shifting emissions upstream
  - Electrification reduces tailpipe emissions but could increase emissions at power plants.
- Freight automation
  - Automation will lower the costs of freight delivery.

Urbanization of Freight Hubs

Traditional "Big Box" Model	Emerging "Hyper-Local" Model
Regional distribution centers	Micro-fulfillment centers
Located in rural/suburban areas	Located throughout urban areas • Closer to denser population
Few very large facilities	Many small facilities • Higher middle-mile emissions
Consolidate shipping into larger vehicles (mostly trucks)	Distribute shipping over smaller vehicles (e.g., vans, cars, cargo bikes) • Lower or zero emission vehicles
Longer delivery distance	Shorter delivery distance • Lower last-mile emissions

Increasing Importance of Non-Exhaust Emissions

- Tailpipe (diesel) PM
  - Carbon-based, carcinogenic aerosol
  - Systemic inflammation
- Brake wear PM
  - Metal-rich, highly reactive aerosol
  - Oxidative stress
- Tire wear PM
  - 6PPD and microplastics
  - Respiratory irritation, allergic reactions

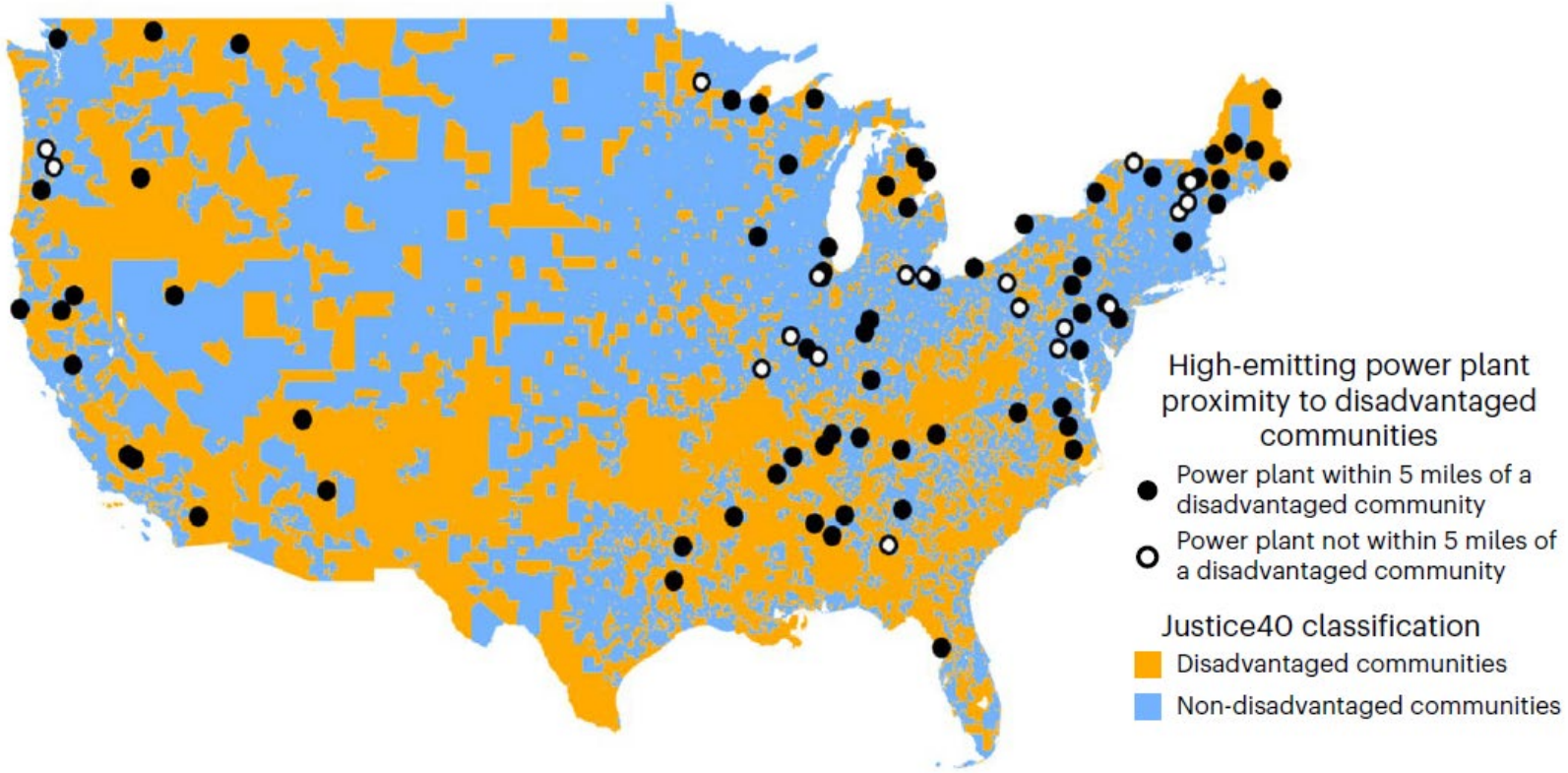


Source: California Air Resources Board, EMFAC2025 model

- Changing health impacts from different composition and toxicity of PM

Shifting Emissions Upstream

Electrification of freight logistics could move emissions exposure from one community to another.

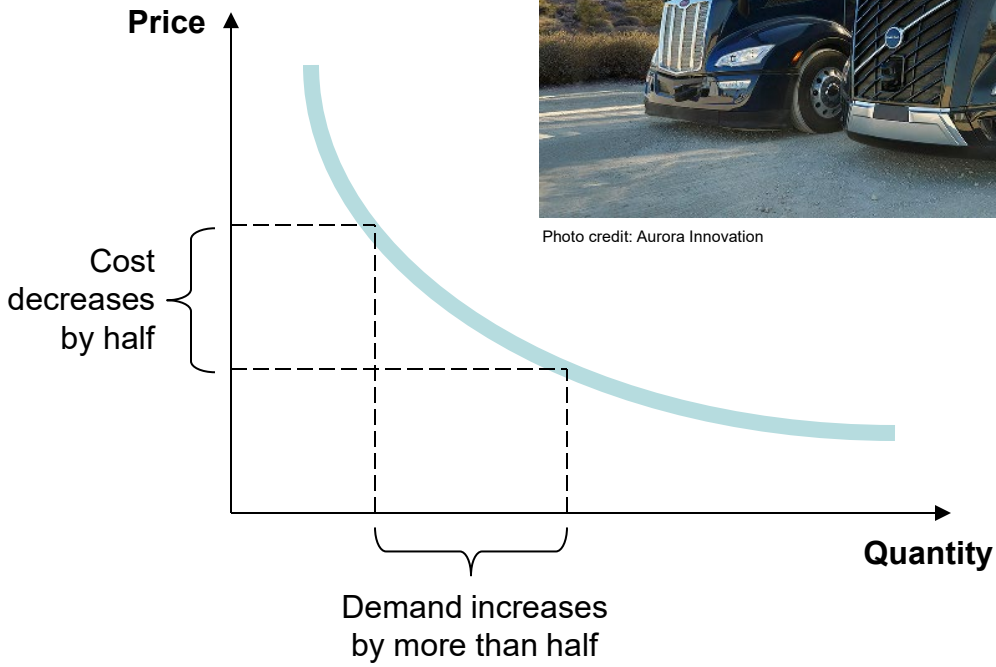


Source: McNeil, W. H., et al. (2025). Impact of truck electrification on air pollution disparities in the United States. *Nature Sustainability*, 8, 276-286.

Freight Automation

- Would the Jevons paradox apply?
  - Lower costs of freight delivery, due to automation, could result in an increased demand for freight delivery.
- How would increased freight delivery impact truck miles traveled, (non-exhaust) emissions, air quality, and public health?

Photo credit: Aurora Innovation



Concluding Remarks

- There are many processes and factors that influence how freight logistics can impact air quality and public health.

- The four emerging trends are intertwined—their interactions and tradeoffs will determine the net air quality and health impacts.
  - Urbanization of freight hubs
  - Increasing importance of non-exhaust emissions
  - Shifting emissions upstream
  - Freight automation

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