MOVES Sensitivity Analysis:

The Impacts of Temperature and Humidity on Emissions

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What is MOVES?

- **MOtor Vehicle Emission Simulator**
- **Replaces MOBILE for on-road vehicle emissions**
  - fundamental redesign
  - extensive updates to model inputs
- **Estimates national, state, and county level inventories of:**
  - criteria pollutants
  - greenhouse gas
  - air toxics
  - energy consumption
- **Approved for use in State Implementation Plan (SIP) and regional conformity analysis**

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MOVES model

- **Facilitates estimation of emissions under user-defined conditions**
  - by replacing national defaults with local inputs
  - through County-Data Manager (CDM)
- **MOVES input parameters:**
  - Meteorology – temperature and humidity
  - Vehicle population
  - Age distributions
  - Vehicle miles travelled (VMT)
  - Average speed distributions
  - Road type distributions
  - Ramp fractions
  - Fuel supply
  - I/M program parameters

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Meteorology data

- **MOVES' default meteorology database**
  - hourly temperature and humidity
  - every county in the country
  - 30 year averages from the National Climatic Data
- **Affect estimates of emissions via**
  - temperature adjustment
  - humidity correction factor for NOx
  - air conditioning adjustment – function of temperature, humidity
- **For SIP and regional conformity analysis, use of local meteorology data encouraged**
- **Thus, understanding the degree to which temperature and humidity affect emissions results is crucial**

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MOVES run

- **MOVES2010a**
- **“National” scale**
- **Gasoline and diesel**
- **All vehicle types, all road types**
- **Pollutants**
  - Hydrocarbons (HC)
  - Carbon monoxide (CO)
  - Oxides of nitrogen (NOx)
  - Total particulate matter ($PM_{2.5}$)
- **Emissions processes**
  - CO, NOx, and PM2.5: cold starts and running
  - HC: cold starts, running, and evaporative

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Methods

- **Humidity**
  - MOVES default relative humidity
    - from 11.5 to 95.3 percent
  - Analysis
    - from 0 to 100 percent in increments of 10
    - at a given temperature between 25 to 100 F
- **Temperature**
  - MOVES default temperature
    - from -24.5 to 107.5 F
  - Analysis
    - from -40 to 120 F in increments of 10 degrees
  - the relationship between temperature and humidity examined to isolate the effect of temperature

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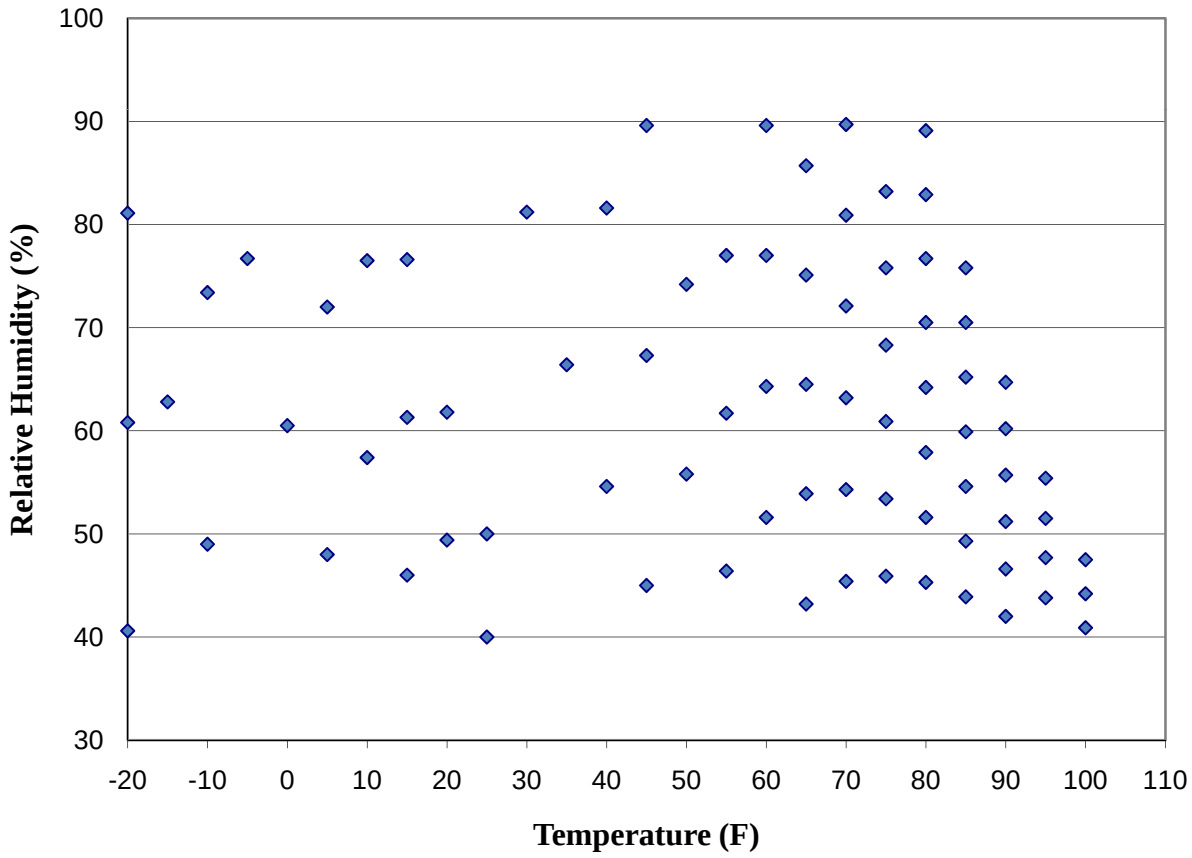
Temperature vs. Relative Humidity



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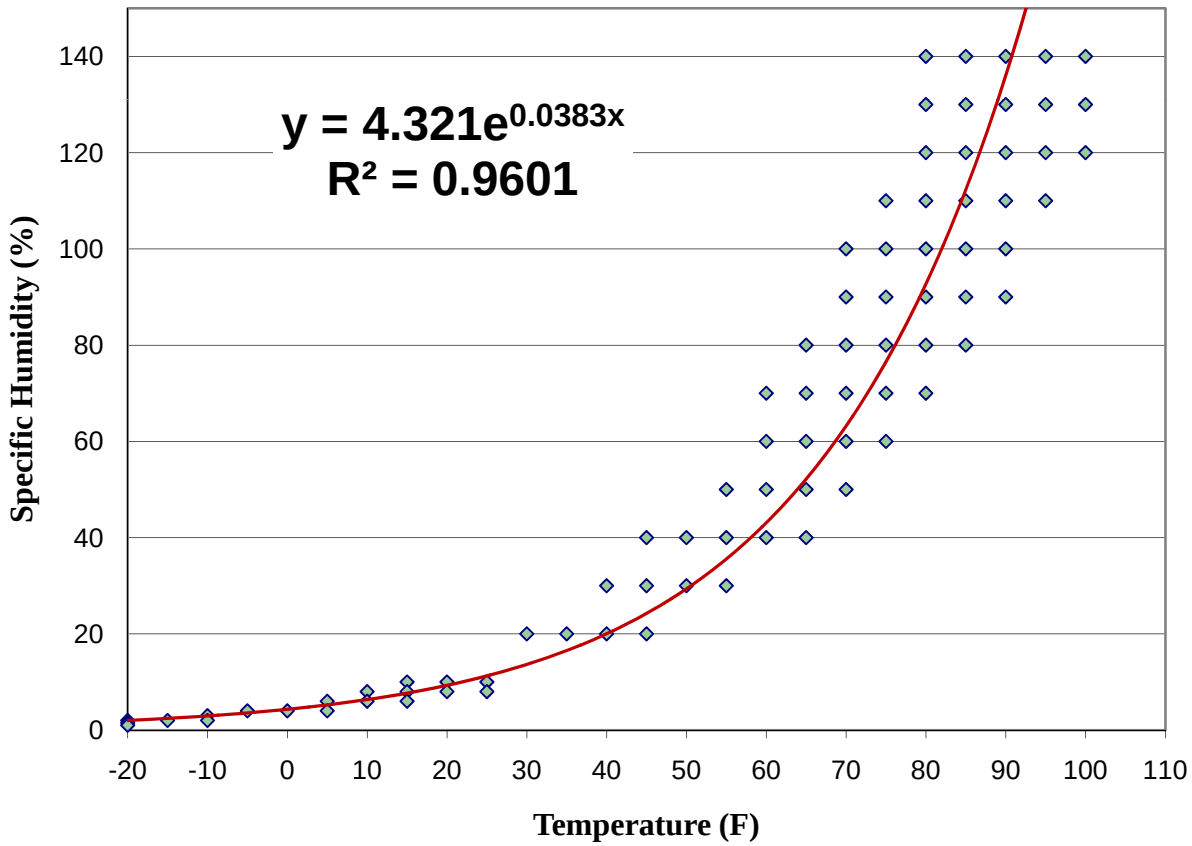
Temperature vs. Specific Humidity



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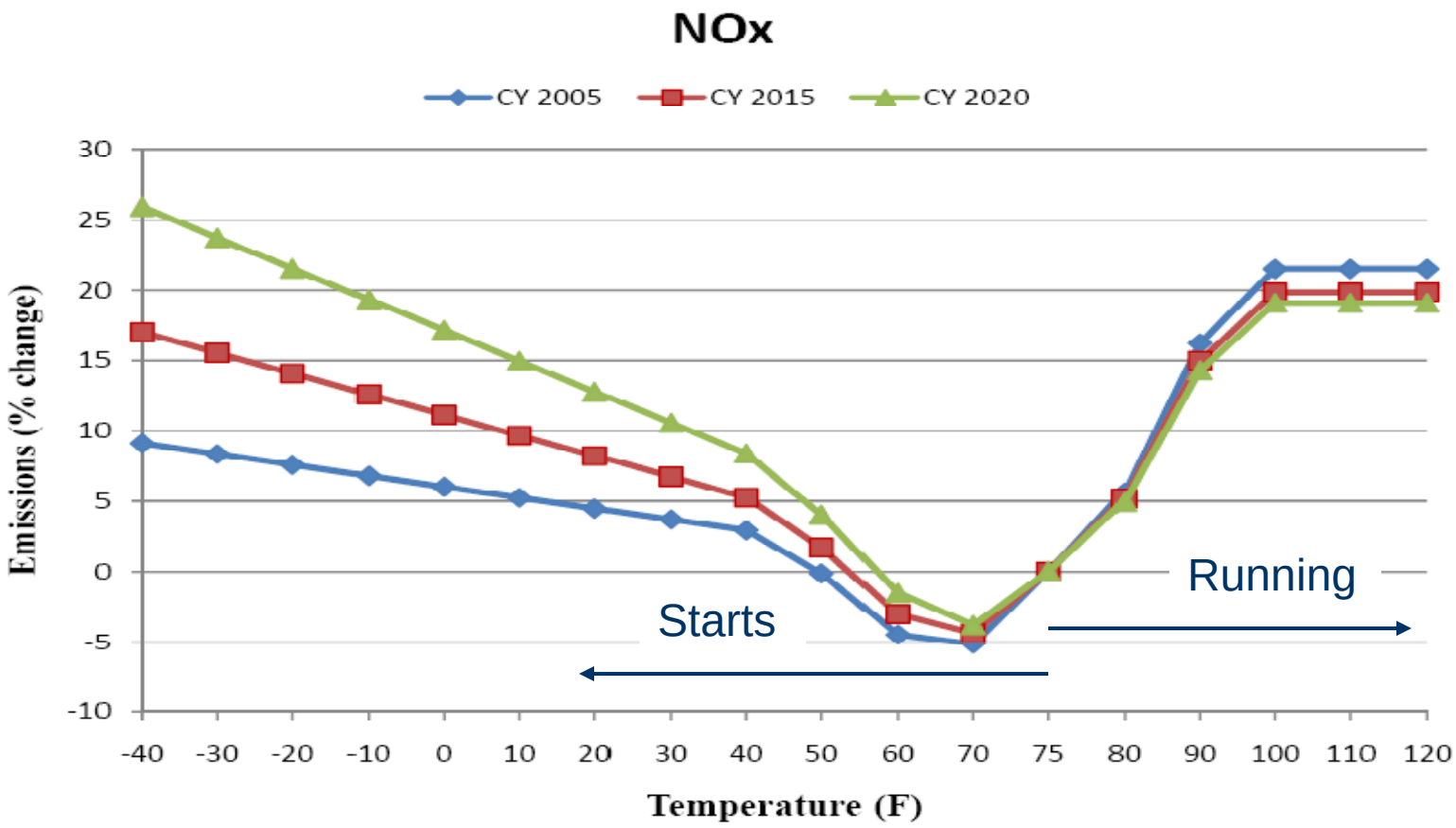
Results

- Aggregate emission estimates of all vehicle types, processes, and road types
- Percent change in emissions in relation to incremental changes in temperature and humidity
- Base temperature: 75 F
- Base humidity: zero percent

Temperature - Gasoline



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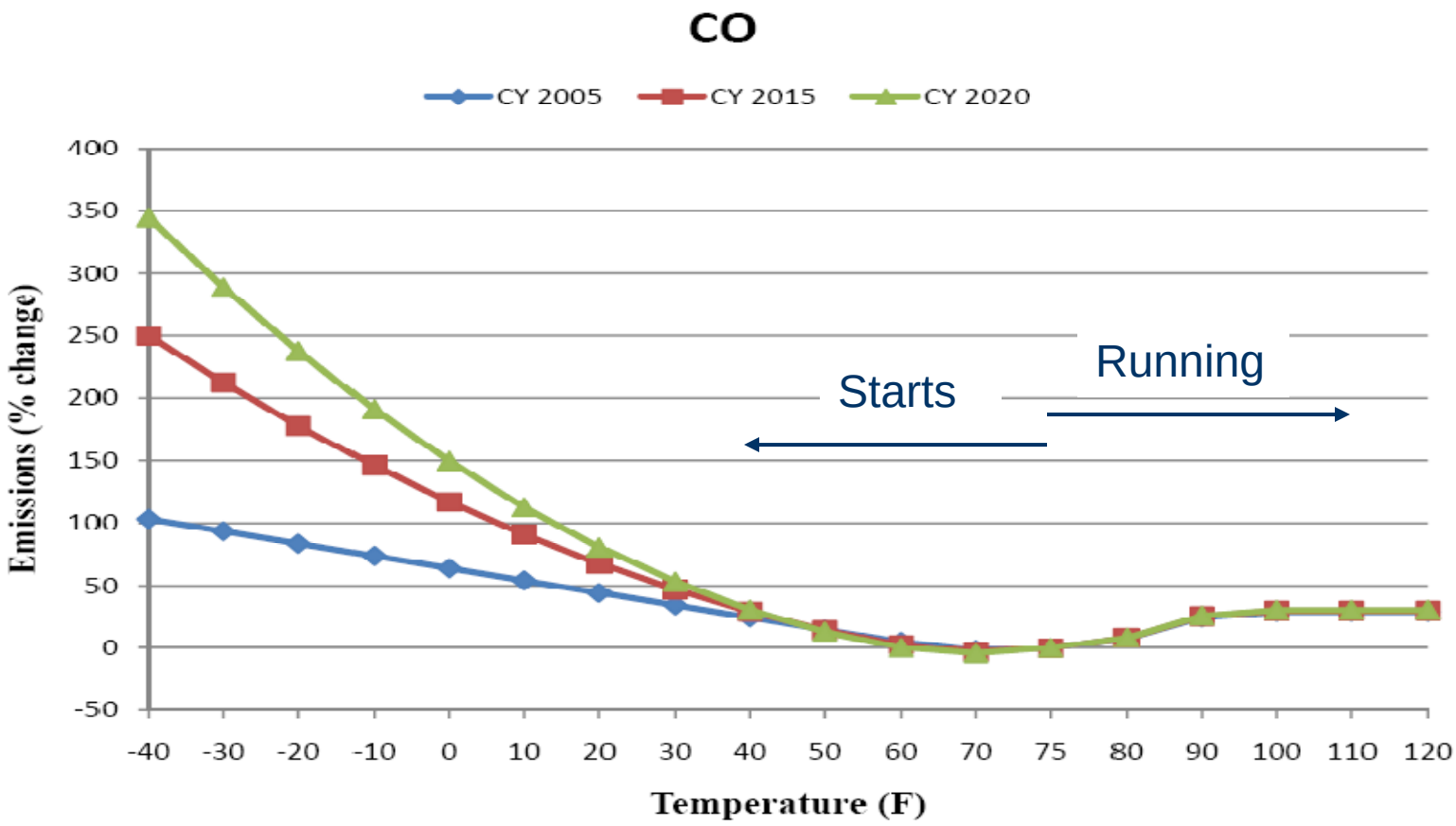
Temperature - Gasoline



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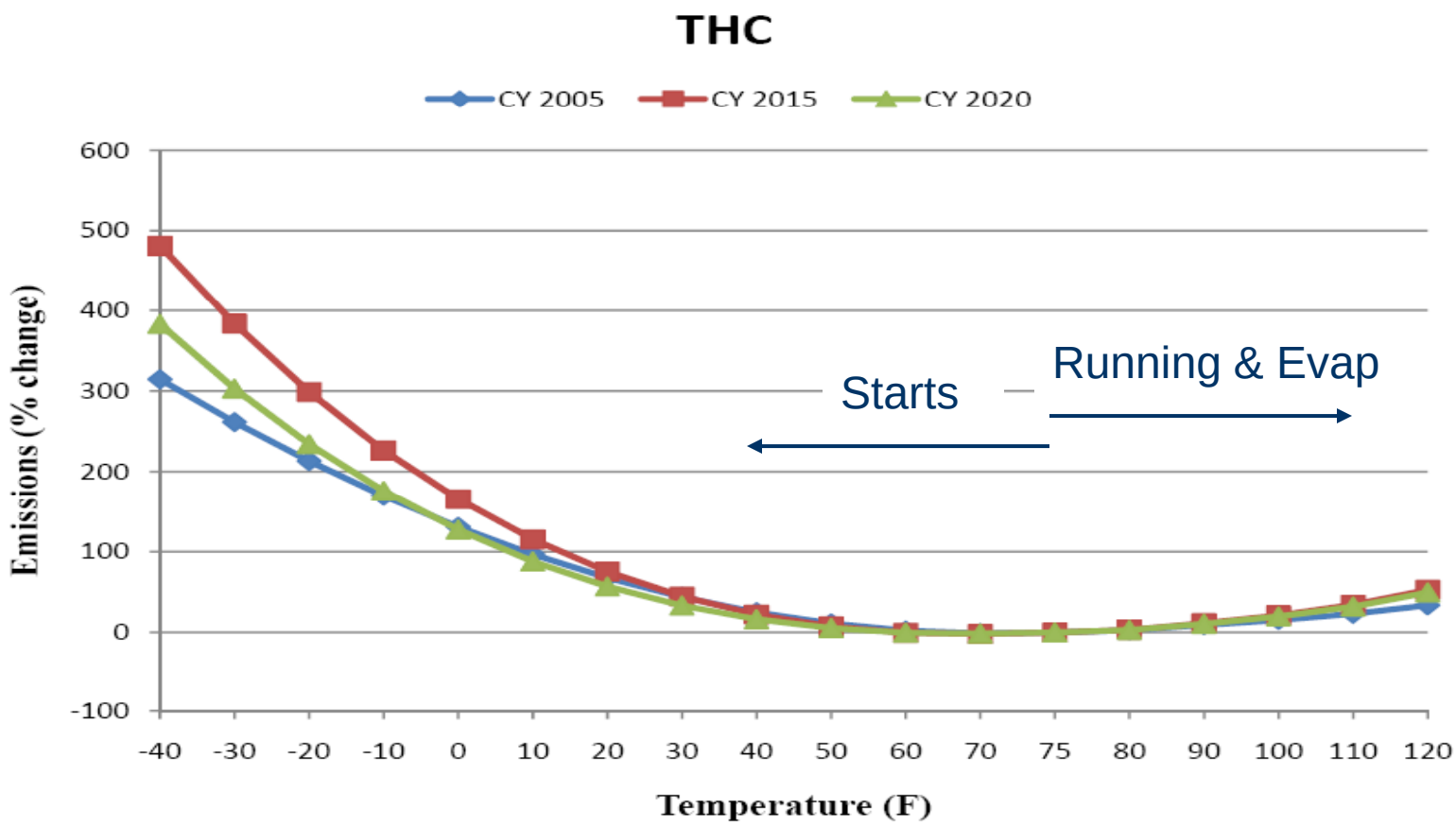
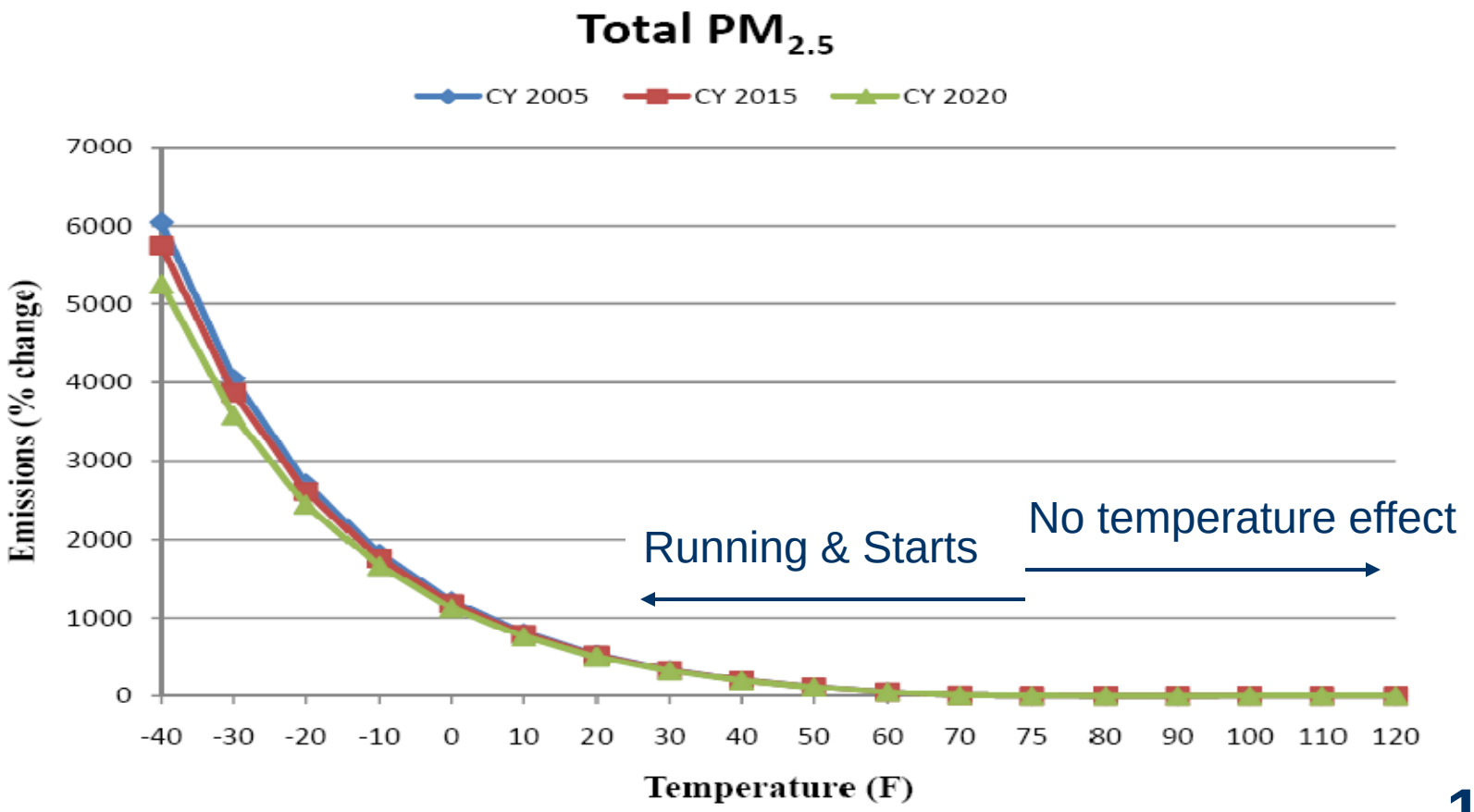
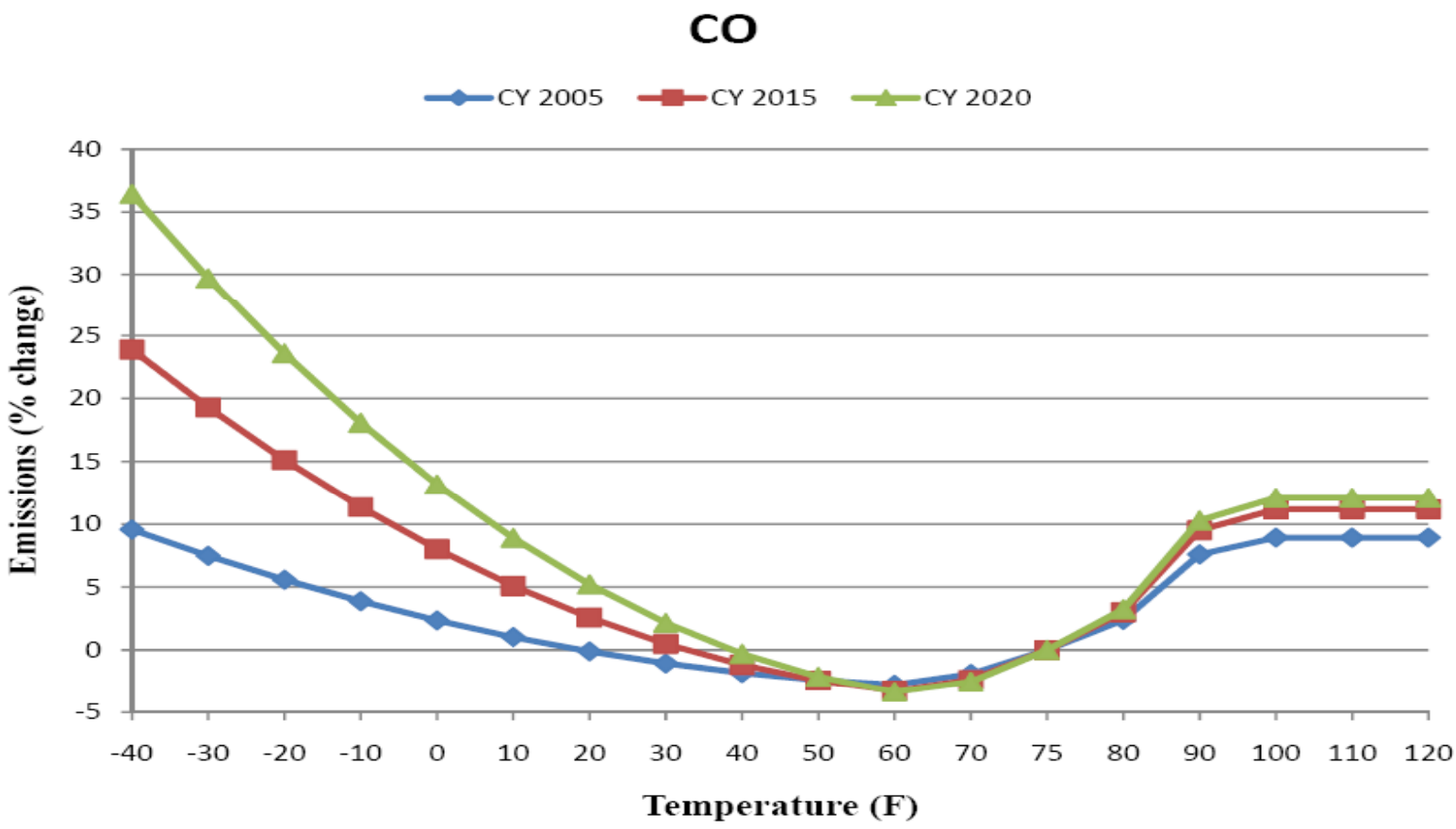
Temperature - Gasoline



Temperature - Gasoline



Temperature - Diesel



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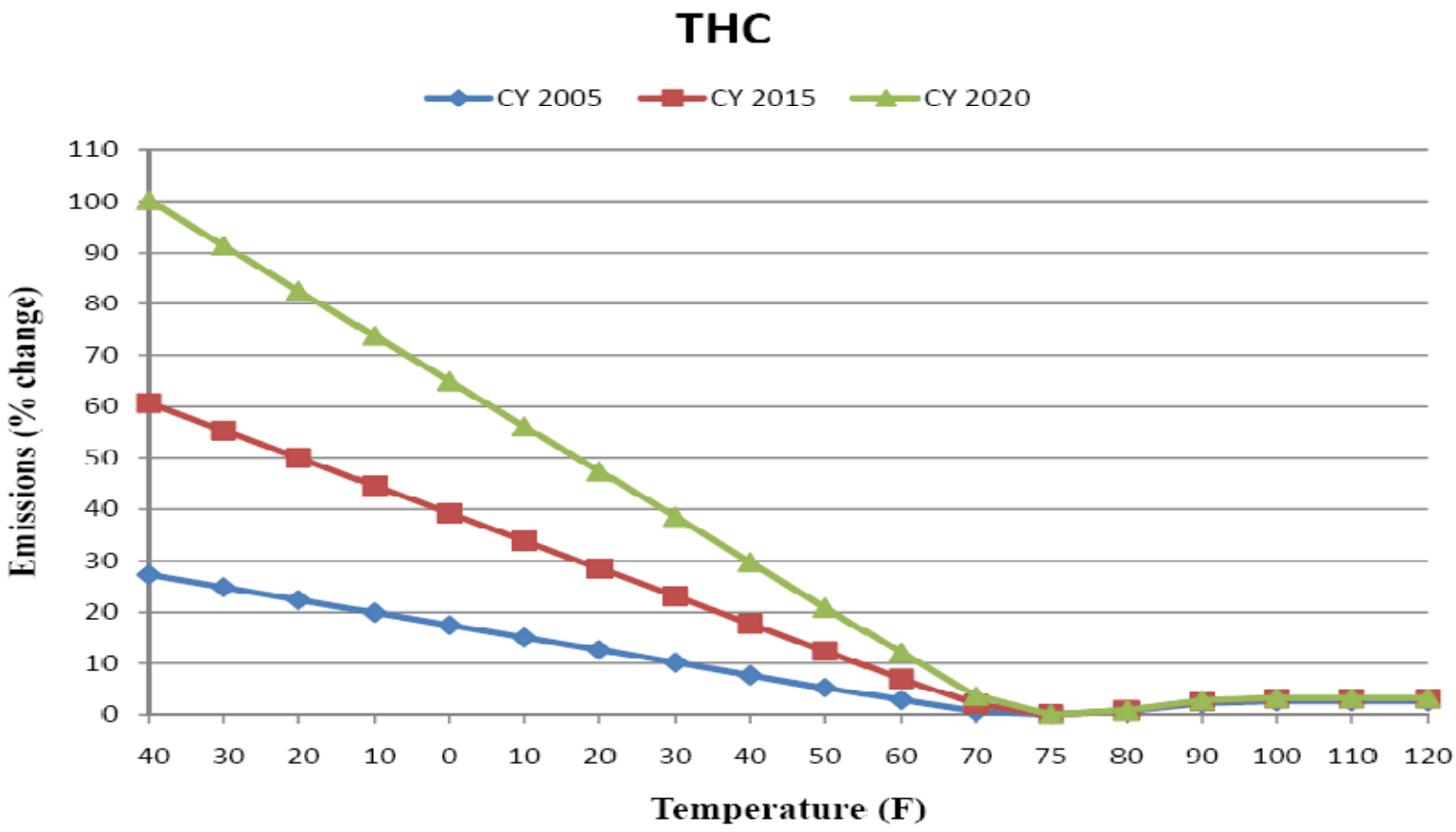
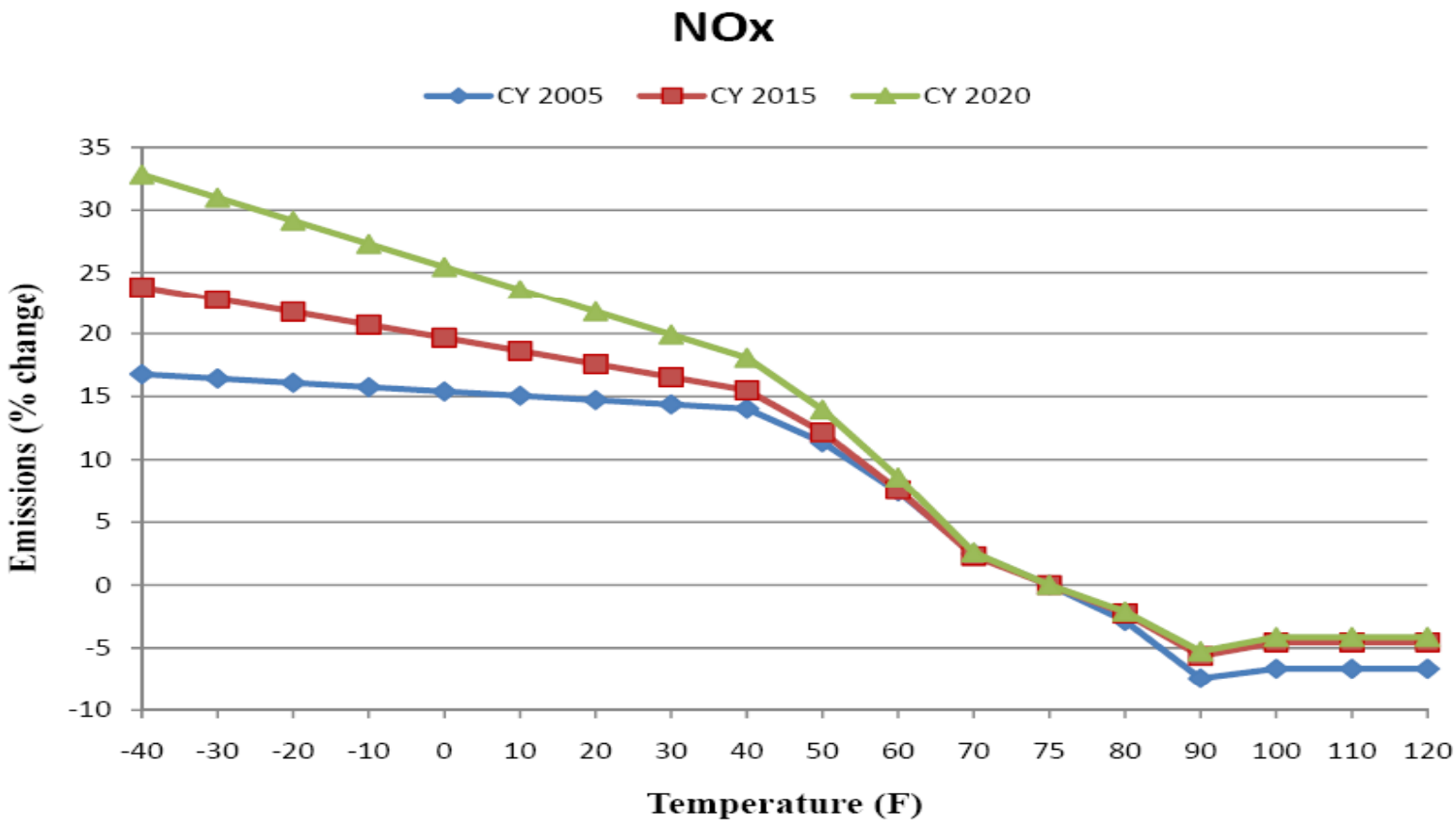
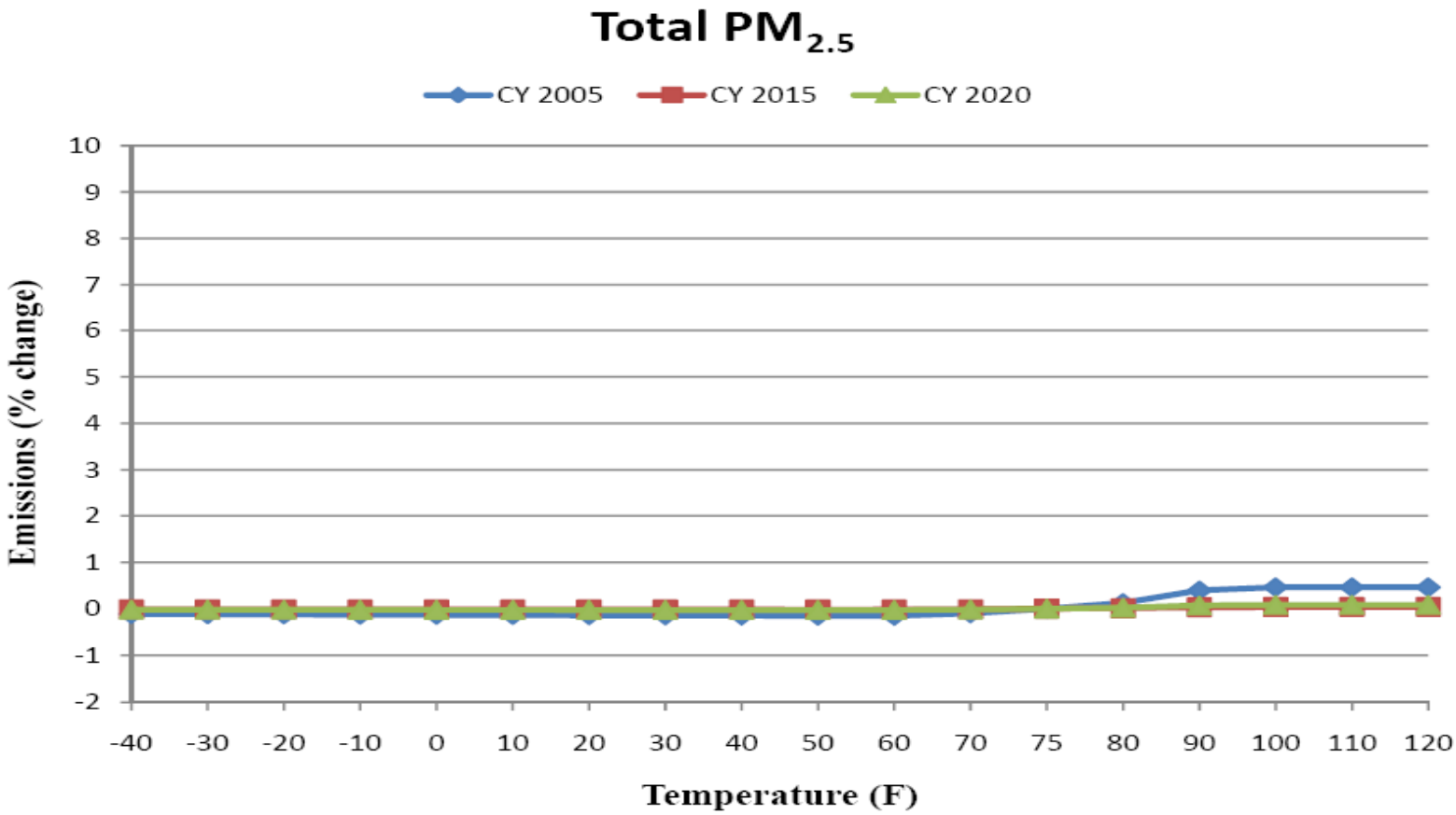
Temperature - Diesel



Temperature - Diesel



Temperature - Diesel



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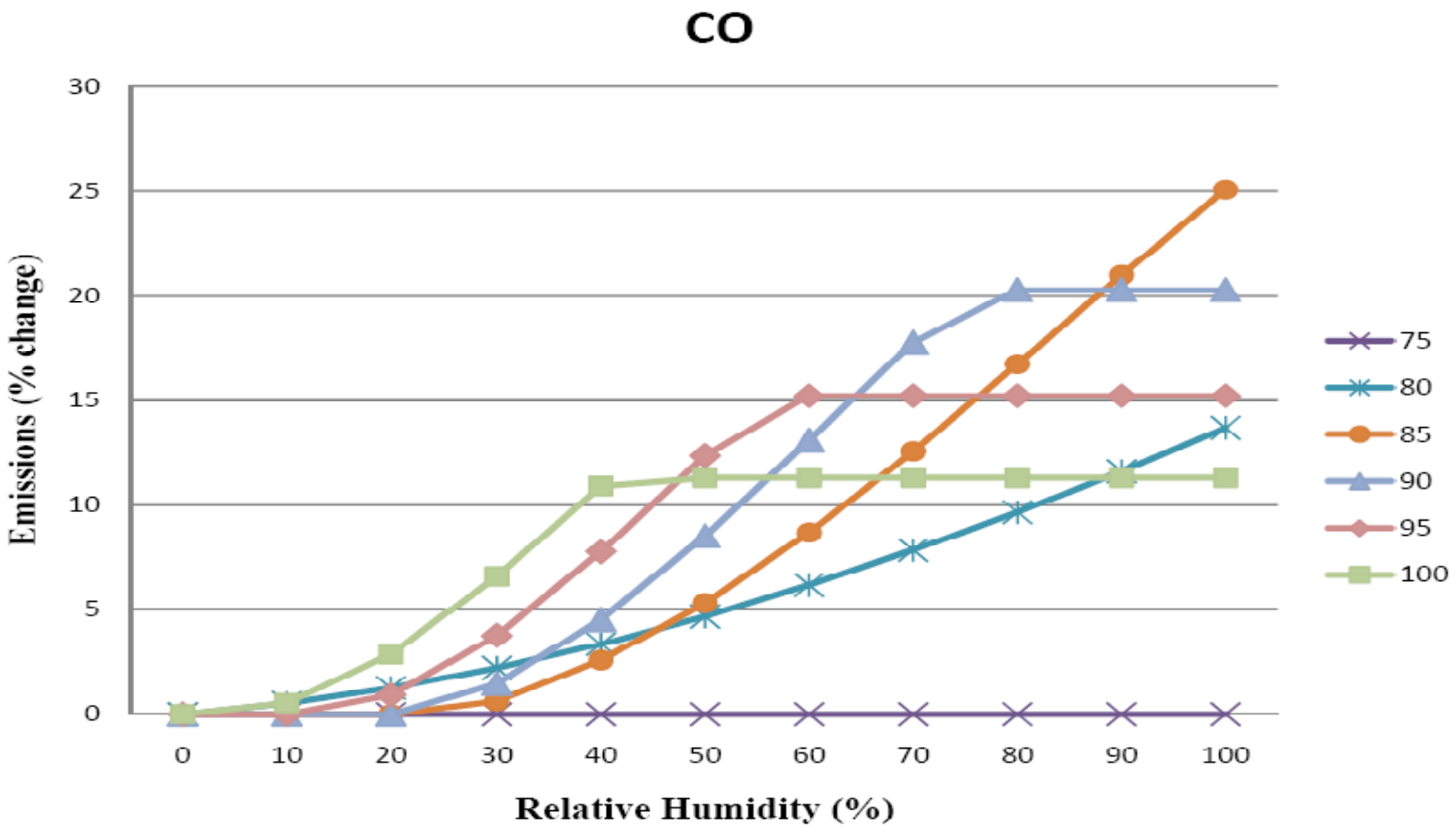
Humidity - Gasoline



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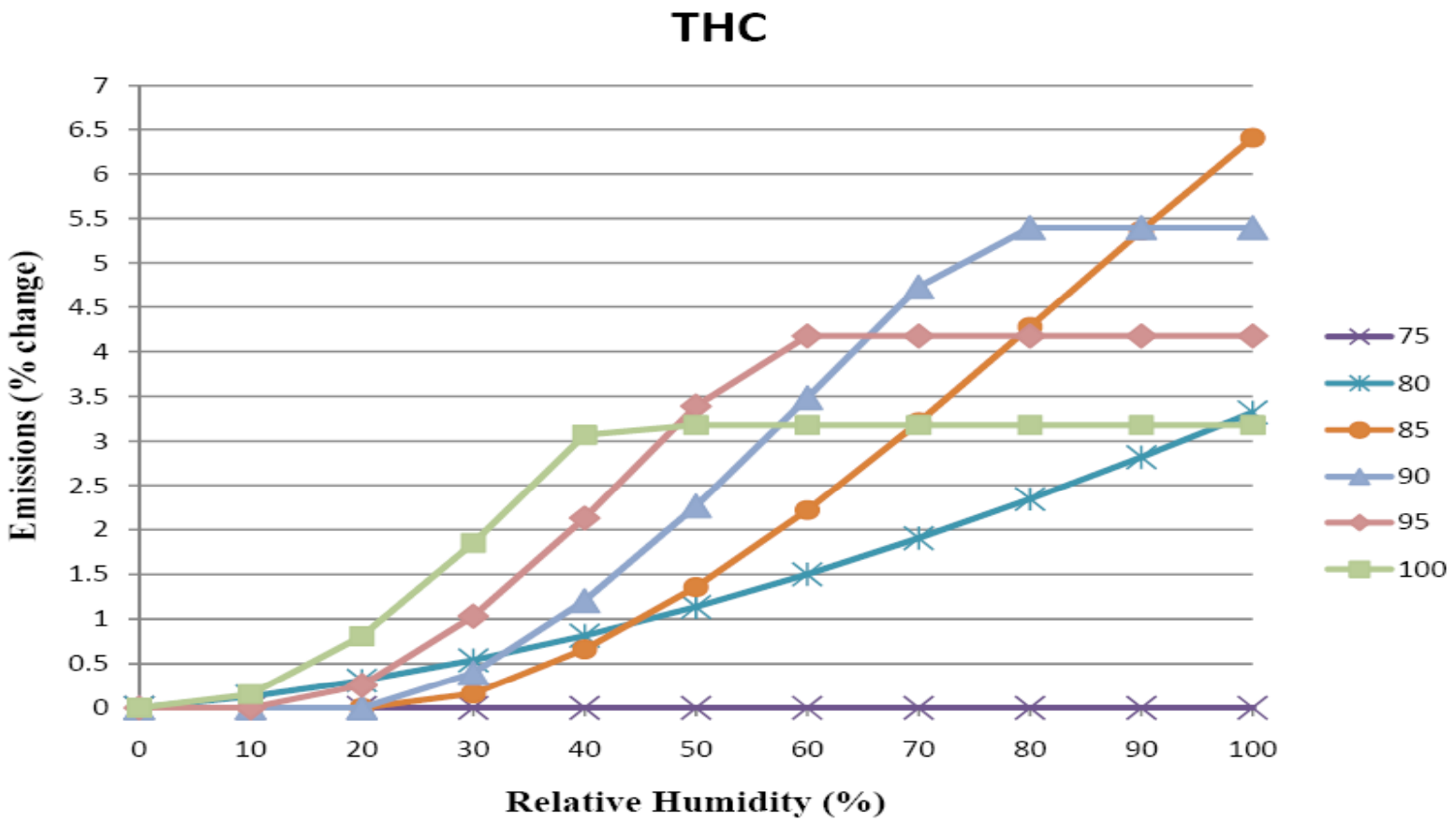
Humidity - Gasoline



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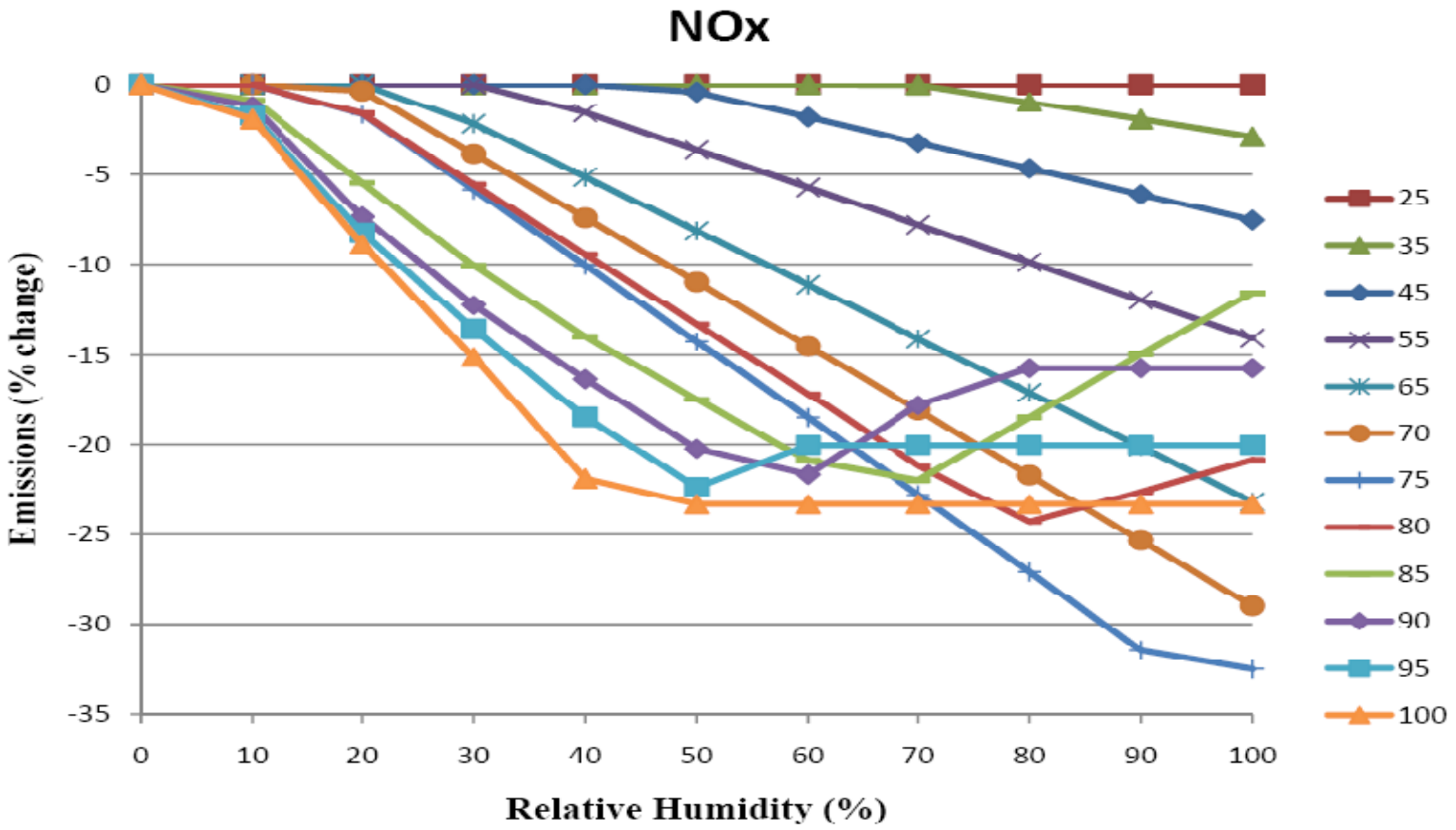
Humidity - Gasoline



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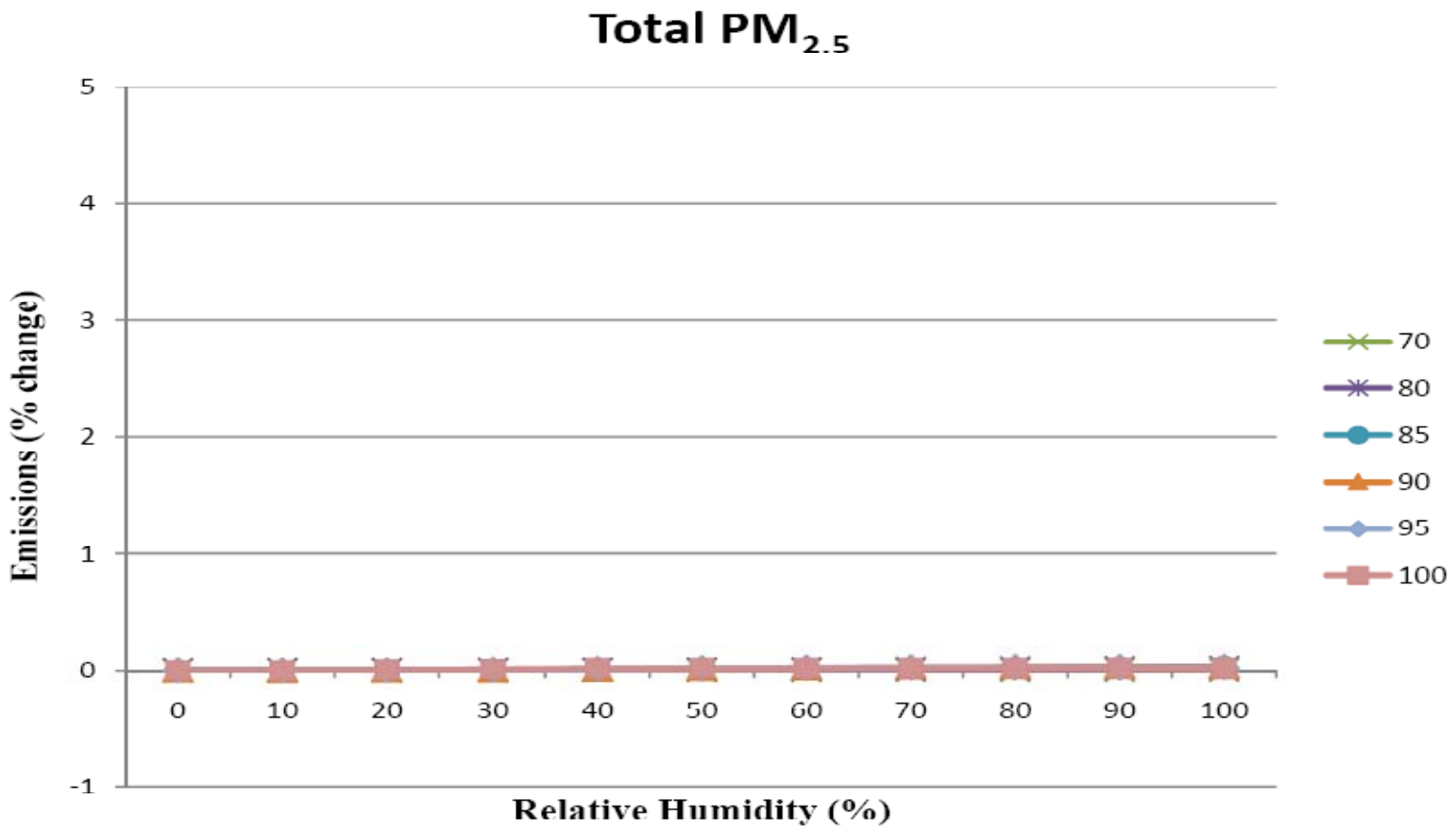
Humidity - Gasoline



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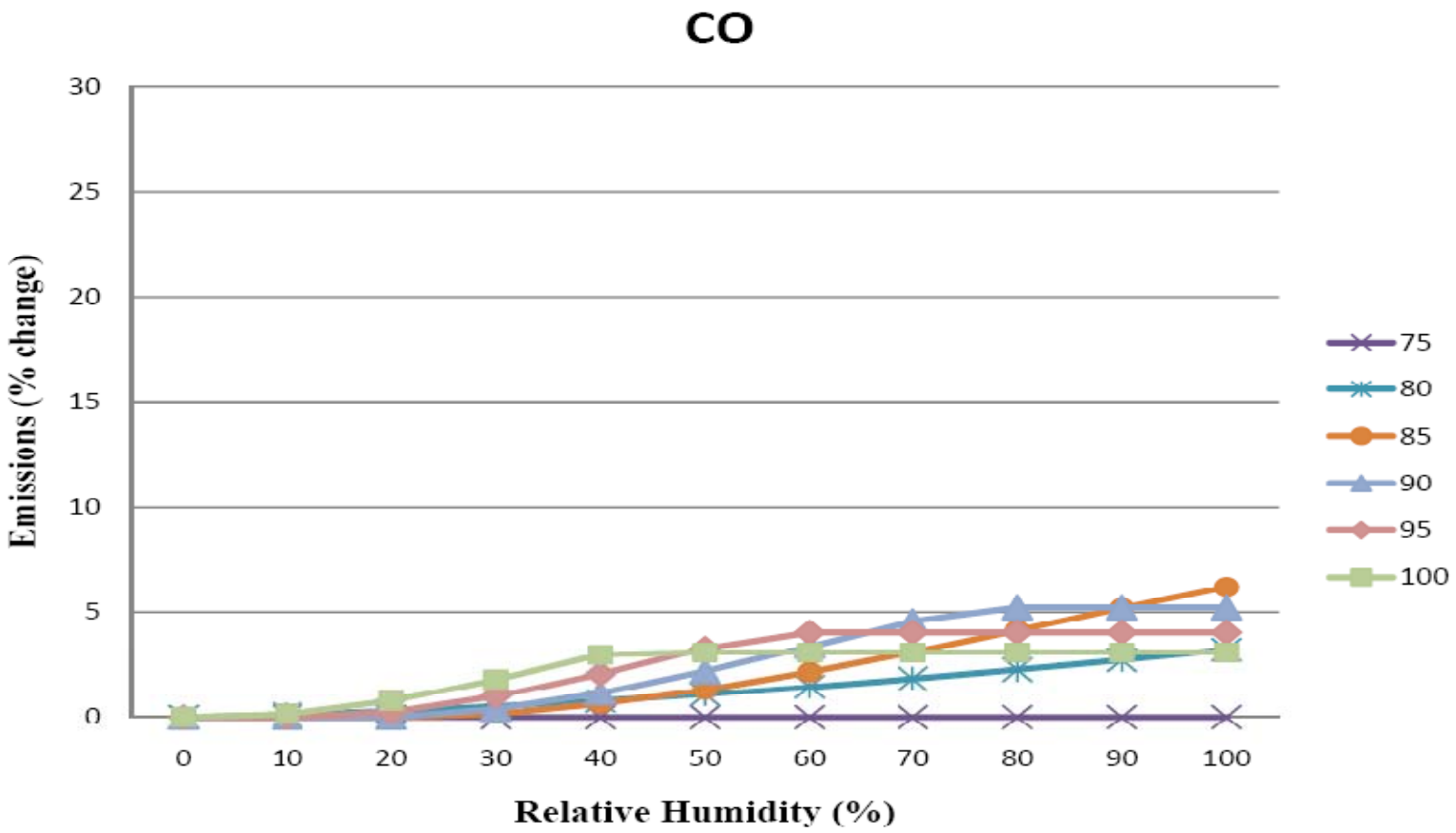
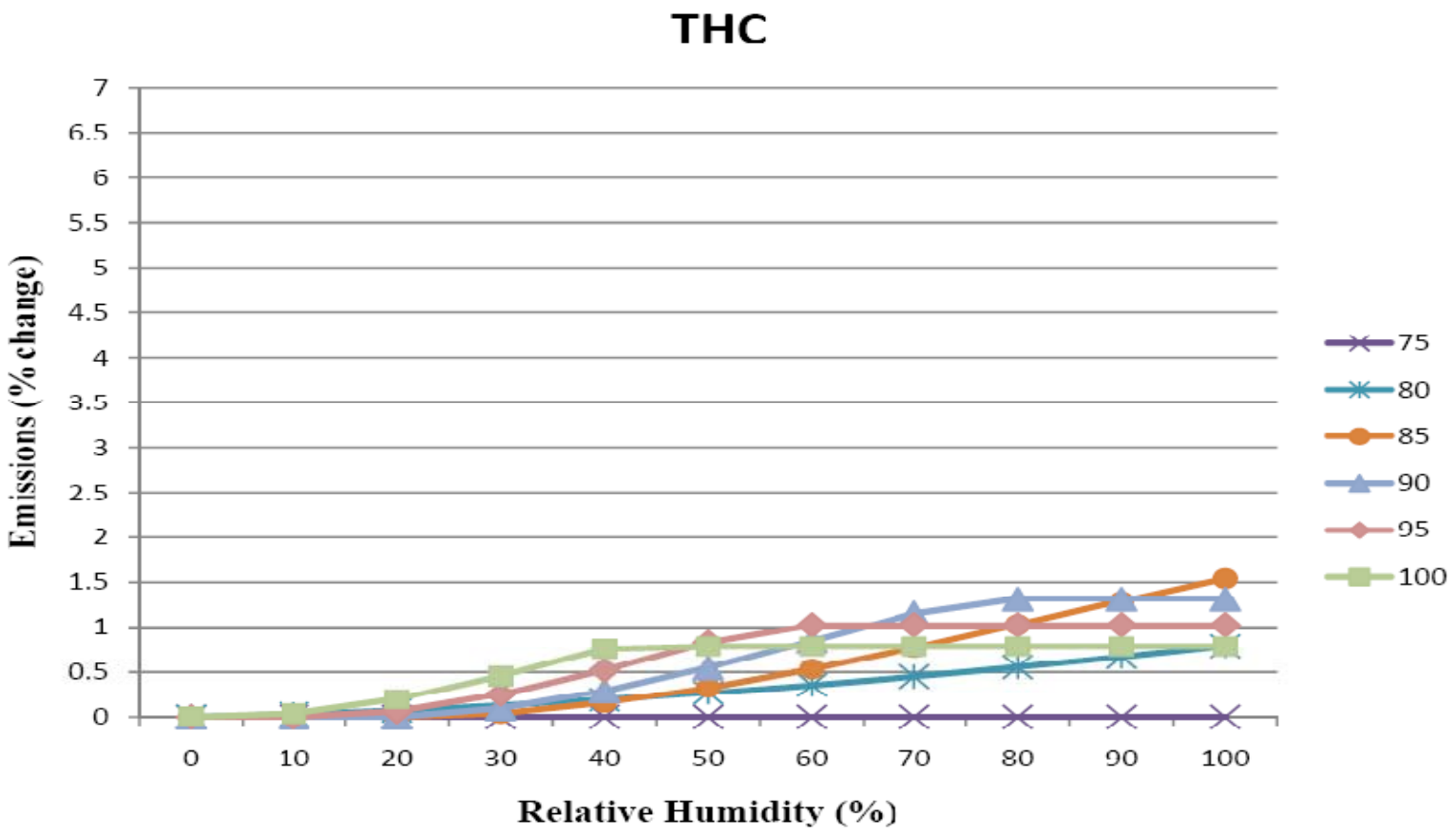
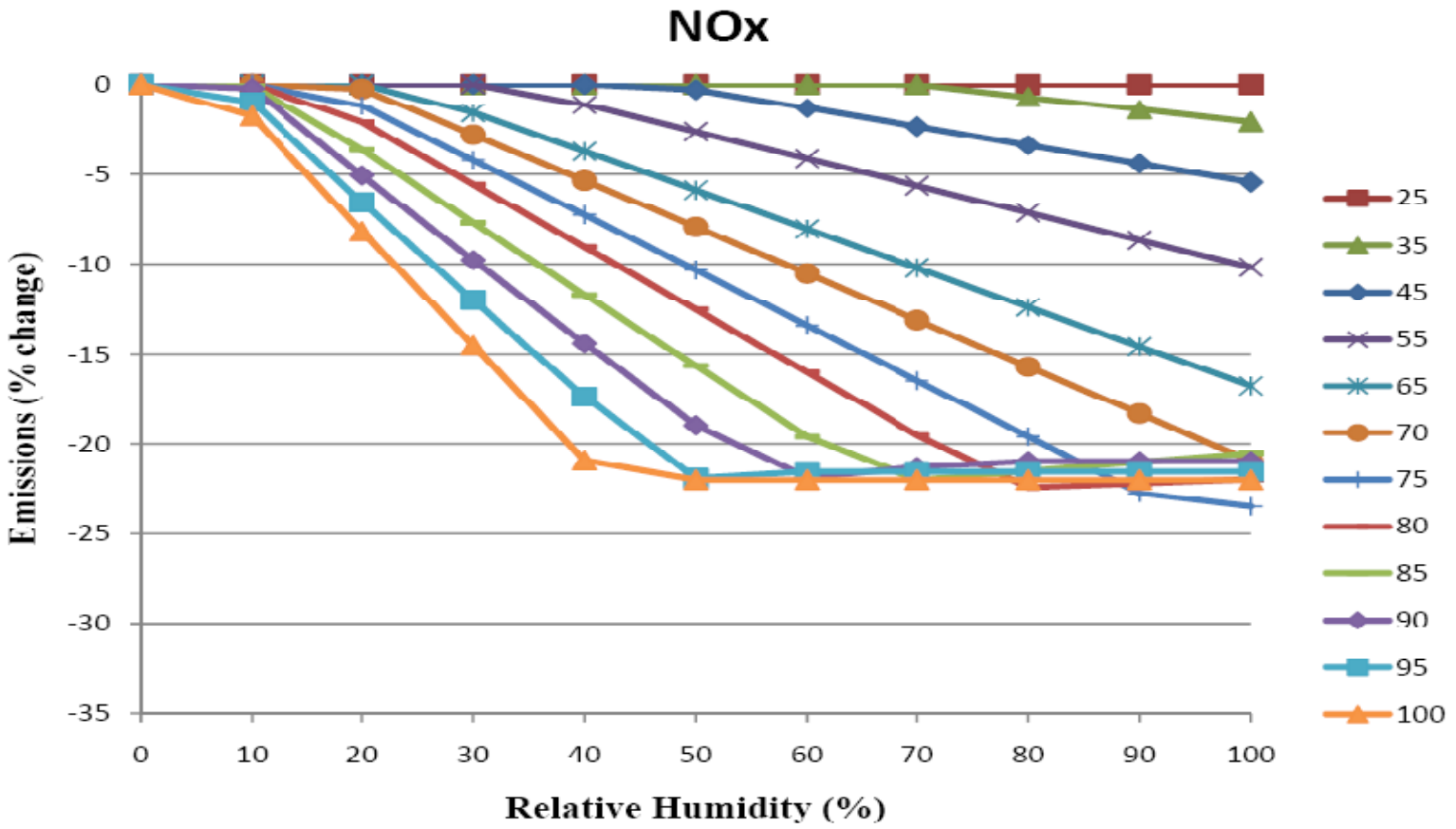
Humidity - Diesel



Humidity - Diesel



Humidity - Diesel



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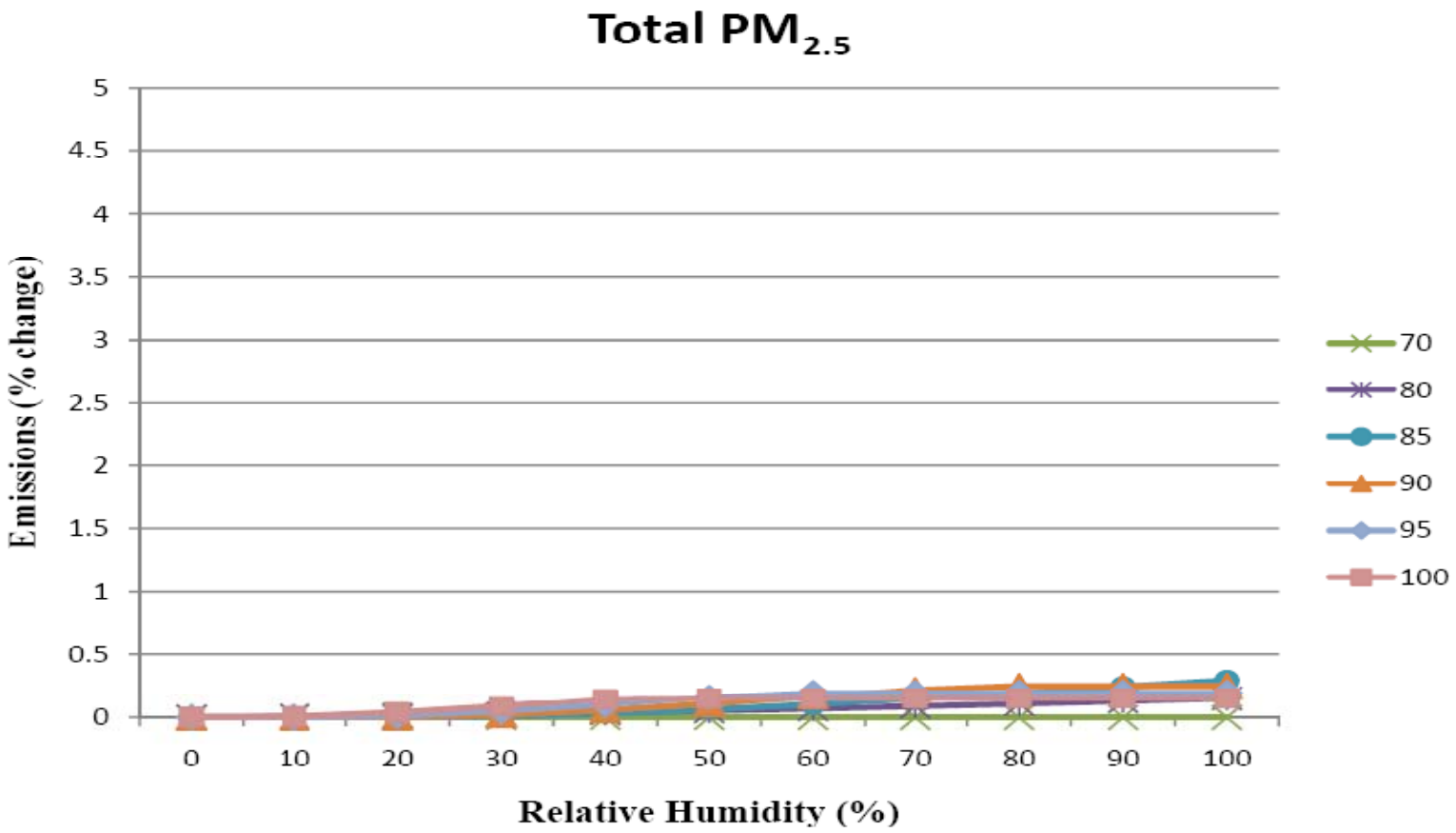
Humidity - Diesel



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Summary

- **Temperature**
  - substantial impact on MOVES' estimates of emissions
    - especially for cold temperatures
  - by fuel type
    - magnitude of impact greater for gasoline vehicles than diesel
    - gasoline
      - PM2.5: most sensitive
      - HC and CO: highly sensitive
    - diesel
      - HC: most sensitive
      - PM2.5: not sensitive
  - by calendar year
    - as vehicles get cleaner, sensitivity to temperature increases

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Summary (cont'd)

- **Humidity**
  - by pollutant
    - HC and CO
      - sensitive for temperatures above 75 F
    - NOx
      - sensitive for temperatures above 25 F
      - exhibit increased sensitivity with increasing humidity
    - PM2.5
      - Not responsive to changes in humidity for both gasoline and diesel
  - by fuel type
    - gasoline vehicles more sensitive than diesel
  - by calendar year
    - sensitivity does not vary (within 1 percent)

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Conclusion

- **Emissions inventories can be estimated more accurately using MOVES if the impacts of temperature and humidity on emissions are considered**
- **Results emphasize the importance of obtaining accurate local meteorological data**
- **Provided assurance for MOVES' ability to generate reasonable estimates for temperature and humidity beyond MOVES default ranges**
- **Future sensitivity analysis**
  - average speed distribution, age distribution, road type distribution, ramp fraction, fuel supply, and I/M program

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References

- *Motor Vehicle Emission Simulator (MOVES) User Guide for MOVES2010a*; EPA-420-B-10-036; U.S. Environmental Protection Agency: Ann Arbor, MI, Aug. 2010; http://www.epa.gov/otaq/models/moves/420b10036.pdf

- *MOVES2010 Highway Vehicle Temperature, Humidity, Air Conditioning, and Inspection and Maintenance Adjustments*; U.S. Environmental Protection Agency: Ann Arbor, MI, March 2010; (in publication); draft MOVES2009 Highway Vehicle Temperature, Humidity, Air Conditioning, and Inspection and Maintenance Adjustments available; http://www.epa.gov/otaq/models/moves/techdocs/420p09003.pdf

- *Analysis of Particulate Matter Emissions from Light-Duty Gasoline Vehicles in Kansas City*; EPA420-R-08-010; U.S. Environmental Protection Agency: Ann Arbor, MI, Apr. 2008; http://www.epa.gov/oms/emission-factors-research/420r08010.pdf

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Thank You Very Much !!!