**Supplementary for**

**Fine-Scale Modeling of Individual Exposures to Ambient PM$_{2.5}$, EC, NO$_x$, and CO for the Coronary Artery Disease and Environmental Exposure (CADEE) Study**

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**Air Exchange Rate Model**

The AER has two parameters ($k_s$ and $k_w$) and five inputs ($A_{\text{leak}}$, $T_{\text{in}}$, $T_{\text{out}}$, $U$, and $V$). Parameters $k_s$ and $k_w$ were set to literature-reported values based on house-specific information on house height (number of stories) and local wind sheltering (Supplementary Material, Tables S1-S3). Using home addresses, the number of stories and local wind sheltering were determined from satellite and street-level images in Google Earth (version 7.1.7.2606; Google, Mountain View, CA, USA). We used house numbers visible in street-level images to verify the participant homes. The number of stories was verified from online county and real estate databases of property records (Zillow, Seattle, WA, USA; Trulia, San Francisco, CA, USA). To determine $V$, we multiplied floor area by a ceiling height of 2.44 m (8 ft). The floor area was obtained from the online county and real estate databases.

We determined $T_{\text{out}}$ and $U$ (10 m elevation) from hourly measurements at Raleigh Durham Airport in Morrisville, NC, USA. We calculated 24 h average $T_{\text{out}}$ and $U$ time-matched to the 24 h average PM$_{2.5}$ measurements. We determined $T_{\text{in}}$ from daily values from the daily participant questionnaires.

We estimate $A_{\text{leak}}$ with a literature-reported leakage area model [1,2]. The $A_{\text{leak}}$ is calculated as

$$A_{\text{leak}} = \frac{NL}{NF} \ [S1]$$

where $NL$ is the normalized leakage and $NF$ is the normalization factor. The $NL$ is predicted from year of construction $Y_{\text{built}}$ and floor area $A_{\text{floor}}$ as described by
where $\beta_0$, $\beta_1$, and $\beta_2$ are regression parameters. The NF is defined as

$\text{NF} = \frac{1000}{A_{\text{floor}}} \left( \frac{H}{2.5} \right)^{0.3}$ \hspace{1cm} \text{[S3]}

where $H$ is the building height. We set $H$ to the number of stories multiplied by a story height of 2.5 m and adding a roof height of 0.5 m (Breen et al., 2010). The $A_{\text{floor}}$ and $Y_{\text{built}}$ were obtained from online county and real estate databases of property records as described above.

The parameters $\beta_0$, $\beta_1$, and $\beta_2$ were estimated by Chan et al. (2005) [2] for low-income homes ($\beta_0=11.1$, $\beta_1=-5.37 \times 10^{-5}$, and $\beta_2=-4.18 \times 10^{-3} \cdot m^{-2}$) and conventional homes ($\beta_0=20.7$, $\beta_1=-1.07 \times 10^{-5}$, and $\beta_2=-2.20 \times 10^{-3} \cdot m^{-2}$). Low-income homes were defined as residences with household incomes below 125% of the poverty guideline. In DEPS, the individual household incomes were not collected. Using 2010 U.S. Census, we examined the median household income at the block group for each home. The household incomes were all substantially above 125% of the 2010 poverty guideline. Therefore, we used the literature-reported parameters for conventional homes in CADEE.

For the airflow from natural ventilation $Q_{\text{nat}}$ can be calculated as:

$Q_{\text{nat}} = \sqrt{Q_{\text{nat,wind}}^2 + Q_{\text{nat,stack}}^2}$ \hspace{1cm} \text{[S4]}

where $Q_{\text{nat,wind}}$ and $Q_{\text{nat,stack}}$ are the airflows from the wind and stack effects, respectively. The $Q_{\text{nat,wind}}$ is defined as:

$Q_{\text{nat,wind}} = C_v A_{\text{nat}} U$ \hspace{1cm} \text{[S5]}

where $C_v$ is the effectiveness of the openings, and the $A_{\text{nat}}$ is the area of the inlet openings. Using literature-reported values, we set $C_v$ to 0.3 and $A_{\text{nat}}$ to one-half of the total area of window and door openings (Breen et al., 2010). The daily participant questionnaires were used to determine number and duration that windows and doors were opened. Window and door opening areas were not collected in CADEE. For windows, we set $A_{\text{nat}}$ to one-half of the literature-reported value of 619 cm$^2$, which is the median daily total window opening area for homes in the same region of central NC as DEPS (Breen et al., 2010). For doors, we set $A_{\text{nat}}$ to one-half of 3600 cm$^2$. The $Q_{\text{nat,stack}}$ is defined as:

$Q_{\text{nat,stack}} = C_D A_{\text{nat}} \sqrt{2 g \Delta H_{\text{NPL}}} |T_{\text{in}} - T_{\text{out}}|/\max\{T_{\text{in}}, T_{\text{out}}\}$ \hspace{1cm} \text{[S6]}

where $C_D$ is the discharge coefficient for the openings, $g$ is the gravitational acceleration, $\Delta H_{\text{NPL}}$ is the height from midpoint of lower window opening to the neutral pressure level (NPL) of the building, and $\max\{T_{\text{in}}, T_{\text{out}}\}$ is the maximum value between $T_{\text{in}}$ and $T_{\text{out}}$. Using literature-reported values, we set $C_D$ to 0.65, midpoint of lower window opening to 0.91 m, and NPL to one-half of $H$ [1].

For the days with operating window fans, the airflow ($Q_{\text{total}}$) was calculated as follows:

$Q_{\text{total}} = Q_{\text{bal}} + \sqrt{Q_{\text{unbal}}^2 + Q_{\text{leak}}^2 + Q_{\text{nat}}^2}$ \hspace{1cm} \text{[7]}

where $Q_{\text{bal}}$ and $Q_{\text{unbal}}$ are balanced and unbalanced flow rate respectively, $Q_{\text{leak}}$ is the flow from leakage, and $Q_{\text{nat}}$ is the flow from natural ventilation. The daily participant questionnaires were used to determine number and duration that window fans were operated. Since whether the window fan system is balanced (i.e. pair of intake and exhaust fan) or unbalanced (i.e. a single intake or exhaust fan) was not recorded, we assume an unbalanced system for all houses with window fan operating ($Q_{\text{unbal}}=0$). $Q_{\text{unbal}}$ was set at 600 ft$^3$/min for each window fan, which is the mid-range value for medium-size window fans (range: 300-900 ft$^3$/min) [3].
Sensitivity Analysis

For the sensitivity analysis of time spent in different microenvironments, we determined exposures (E) as defined by

\[ E = F_{pex} C_{out} \] (8)

where \( F_{pex} \) is the personal exposure factor (dimensionless), and \( C_{out} \) is the outdoor concentration. The \( F_{pex} \) is defined by

\[ F_{pex} = f_{in\_home} F_{inf\_home} + (f_{in\_work} + f_{in\_other\_bldg}) F_{inf\_other\_bldg} + f_{in\_vehicle} F_{inf\_vehicle} + f_{out} F_{out} \]

where \( f_{in\_home}, f_{in\_work}, f_{in\_other\_bldg}, f_{in\_vehicle}, f_{out} \) are the fraction of day spent in indoors at home, work, other buildings; inside vehicles; outdoors, respectively; and \( F_{inf\_home}, F_{inf\_other\_bldg}, F_{inf\_vehicle}, F_{out} \) are the infiltration (i.e., attenuation) factors for home, other buildings including work, vehicles, outdoors, respectively. The \( F_{inf\_home} \) is defined by a steady-state mass-balance infiltration model described by

\[ F_{inf\_home} = (P AER)/(AER + k_i) \] (9)

where \( P \) is the penetration coefficient (dimensionless), \( AER \) is the air exchange rate (h\(^{-1}\)), and \( k_i \) is the indoor removal rate (h\(^{-1}\)). We set \( AER \) to the median value (0.5 h\(^{-1}\)) measured from homes in the same region of North Carolina as CADEE homes [4]. We used the same parameter as described in the main paper. For PM\(_{2.5}\), \( P \) and \( k_i \) were previously estimated from homes in the same region of NC as CADEE (\( P = 0.84, k_i = 0.21 \) h\(^{-1}\)) [4,5]. For EC, NO\(_x\), CO, \( P \) and \( k_i \) were obtained from literature-reported values (\( P = 0.98, 1.00, 1.00; k_i = 0.29, 0.5, 0 \) h\(^{-1}\); respectively) [6–8]. This yields \( F_{inf\_home} \) of 0.59, 0.62, 0.50, 1.0 for PM\(_{2.5}\), EC, NO\(_x\), CO, respectively.

For PM\(_{2.5}\), EC, NO\(_x\), CO, we set \( F_{inf\_other\_bldg} \) and \( F_{inf\_vehicle} \) to literature-reported values (\( F_{inf\_other\_bldg} = 0.64, 0.59, 1.00, 1.00; F_{inf\_vehicle} = 0.44, 0.44, 0.80, 1.00; \) respectively) [8–10]. For outdoors, \( F_{out} \) is always 1.0.

For the five different microenvironments that participants can spend their time, the infiltration factors (\( F_{inf\_home}, F_{inf\_other\_bldg}, F_{inf\_vehicle}, F_{out} \)) vary by a range (max-min) and factor (max/min) of (0.44-1.00; factor of 2.3) for PM\(_{2.5}\), (0.44-1.00; factor of 2.3) for EC, (0.50-1.00; factor of 2.0) for NO\(_x\), (1.00-1.00; factor of 1.0) for CO. Therefore, changes in the time spent in ME with substantially different infiltration factors (e.g., indoors versus outdoors) can produce substantial changes in the exposures for PM\(_{2.5}\), EC, NO\(_x\), but have little or no effect on exposures to CO.
Table S1. Stack coefficient \( k_s \) \([(L/s)^2/(cm^4 K)]\).

| House Height (Stories) | One     | Two     | Three    |
|------------------------|---------|---------|----------|
| Stack coefficient      | 0.000145| 0.000290| 0.000435 |

\(^1\) ASHRAE Handbook-Fundamentals, 2009.

Table S2. Wind coefficient \( k_w \) \([(L/s)^2/(cm^4 (m/s)^2)]\).

| Shelter Class | House Height (Stories) | One     | Two     | Three    |
|---------------|------------------------|---------|---------|----------|
| 1             | 0.000319               | 0.000420| 0.000494|
| 2             | 0.000246               | 0.000325| 0.000382|
| 3             | 0.000174               | 0.000231| 0.000271|
| 4             | 0.000104               | 0.000137| 0.000161|
| 5             | 0.000032               | 0.000042| 0.000049|

\(^1\) ASHRAE Handbook-Fundamentals, 2009 [11].

Table S3. Local Sheltering\(^1\).

| Shelter Class | Description |
|---------------|-------------|
| 1             | No obstructions or local sheltering. |
| 2             | Typical shelter for an isolated rural house |
| 3             | Typical shelter caused by other buildings across street from building under study |
| 4             | Typical shelter for urban buildings on larger lots where sheltering obstacles are more than one building height away |
| 5             | Typical shelter produced by buildings or other structures immediately adjacent (closer than one building height): e.g., neighboring houses on same side of street, trees, bushes, etc. |

\(^1\) ASHRAE Handbook-Fundamentals, 2009 [11].

Table S4. Male sedentary ventilation rates\(^2\).

| Ventilation Rates (L/min/kg body weight) |
|-----------------------------------------|
| 1 year old                              | 0.40 |
| 2 years old                             | 0.34 |
| 3-5 years old                           | 0.25 |
| 6-10 years old                          | 0.16 |
| 11-15 years old                         | 0.10 |
| 16-20 years old                         | 0.08 |
| 21-30 years old                         | 0.06 |
| 31-60 years old                         | 0.07 |
| 61-80 years old                         | 0.08 |
| 81 years and older                      | 0.09 |

\(^2\) Breen et al., 2019 [3].

Table S5. Male light intensity ventilation rates\(^2\).

| Ventilation Rates (L/min/kg body weight) |
|-----------------------------------------|
| 1 year old                              | 1.01 |
| 2 years old                             | 0.83 |
| Age Group                  | Ventilation Rates (L/min/kg body weight) |
|---------------------------|-----------------------------------------|
| 3-5 years old             | 0.63                                    |
| 6-10 years old            | 0.38                                    |
| 11-15 years old           | 0.24                                    |
| 16-20 years old           | 0.18                                    |
| 21-30 years old           | 0.15                                    |
| 31-70 years old           | 0.16                                    |
| 71-80 years old           | 0.17                                    |
| 81 years and older        | 0.18                                    |

2 Breen et al., 2019 [3].

Table S6. Male moderate intensity ventilation rates$

| Age Group      | Ventilation Rates (L/min/kg body weight) |
|----------------|-----------------------------------------|
| 1 year old     | 1.82                                    |
| 2 years old    | 1.54                                    |
| 3-5 years old  | 1.12                                    |
| 6-10 years old | 0.71                                    |
| 11-15 years old| 0.47                                    |
| 16-20 years old| 0.38                                    |
| 21-40 years old| 0.34                                    |
| 41-50 years old| 0.35                                    |
| 51-60 years old| 0.37                                    |
| 61-70 years old| 0.34                                    |
| 71-80 years old| 0.36                                    |
| 81 years and older| 0.38                                 |

2 Breen et al., 2019 [3].

Table S7. Male vigorous intensity ventilation rates$

| Age Group      | Ventilation Rates (L/min/kg body weight) |
|----------------|-----------------------------------------|
| 1 year old     | 3.57                                    |
| 2 years old    | 2.87                                    |
| 3-5 years old  | 2.11                                    |
| 6-10 years old | 1.38                                    |
| 11-15 years old| 0.91                                    |
| 16-20 years old| 0.69                                    |
| 21-30 years old| 0.64                                    |
| 31-40 years old| 0.62                                    |
| 41-50 years old| 0.63                                    |
| 51-60 years old| 0.64                                    |
| 61-70 years old| 0.61                                    |
| 71-80 years old| 0.63                                    |
| 81 years and older| 0.70                                 |

2 Breen et al., 2019 [3].

Table S8. Female sedentary ventilation rates$

| Age Group      | Ventilation Rates (L/min/kg body weight) |
|----------------|-----------------------------------------|
| 1 year old     | 0.42                                    |
| 2 years old    | 0.35                                    |
| 3-5 years old  | 0.25                                    |
| 6-10 years old | 0.16                                    |
| 11-15 years old| 0.09                                    |
| 16-20 years old| 0.07                                    |
| 21-50 years old| 0.06                                    |
| 51-80 years old| 0.07                                    |
| 81 years and older| 0.08                                 |

2 Breen et al., 2019 [3].
### Table S9. Female light intensity ventilation rates

| Age Group                  | Ventilation Rates (L/min/kg body weight) |
|----------------------------|------------------------------------------|
| 1 year old                 | 1.04                                     |
| 2 years old                | 0.89                                     |
| 3-5 years old              | 0.60                                     |
| 6-10 years old             | 0.38                                     |
| 11-15 years old            | 0.22                                     |
| 16-20 years old            | 0.17                                     |
| 21-40 years old            | 0.15                                     |
| 41-60 years old            | 0.16                                     |
| 61-70 years old            | 0.14                                     |
| 71 years and older         | 0.16                                     |

*2 Breen et al., 2019 [3].

### Table S10. Female moderate intensity ventilation rates

| Age Group                  | Ventilation Rates (L/min/kg body weight) |
|----------------------------|------------------------------------------|
| 1 year old                 | 1.87                                     |
| 2 years old                | 1.58                                     |
| 3-5 years old              | 1.11                                     |
| 6-10 years old             | 0.71                                     |
| 11-15 years old            | 0.43                                     |
| 16-20 years old            | 0.35                                     |
| 21-30 years old            | 0.32                                     |
| 31-40 years old            | 0.30                                     |
| 41-50 years old            | 0.32                                     |
| 51-60 years old            | 0.33                                     |
| 61-70 years old            | 0.28                                     |
| 71-80 years old            | 0.30                                     |
| 81 years and older         | 0.33                                     |

*2 Breen et al., 2019 [3].

### Table S11. Female vigorous intensity ventilation rates

| Age Group                  | Ventilation Rates (L/min/kg body weight) |
|----------------------------|------------------------------------------|
| 1 year old                 | 3.24                                     |
| 2 years old                | 2.81                                     |
| 3-5 years old              | 1.90                                     |
| 6-10 years old             | 1.33                                     |
| 11-15 years old            | 0.85                                     |
| 16-20 years old            | 0.69                                     |
| 21-30 years old            | 0.63                                     |
| 31-40 years old            | 0.59                                     |
| 41-50 years old            | 0.64                                     |
| 51-60 years old            | 0.61                                     |
| 61-70 years old            | 0.53                                     |
| 71-80 years old            | 0.58                                     |
| 81 years and older         | 0.63                                     |

*2 Breen et al., 2019 [3].
Figure 1. Percentage of time spent per day (%) (top) and daily dose (ug/m$^2$) (bottom) of total Modeled PM2.5 for each microenvironment (home in, home out, work in, work out, other in, other out, in vehicle) for each participant. Results are sorted by median values of the total 24-hour daily dose from highest to lowest as shown in Figure 2. Shown are medians with 25th and 75th percentiles, and whiskers for minimum and maximum values.
Figure S2. Percentage of time spent per day(%) (top) and daily dose (ug/m²) (bottom) of total Modeled EC for each microenvironment (home in, home out, work in, work out, other in, other out, in vehicle) for each participant. Results are sorted by median values of the total 24-hour daily dose from highest to lowest as shown in Figure 2. Shown are medians with 25th and 75th percentiles, and whiskers for minimum and maximum values.
Figure S3. Percentage of time spent per day(%) (top) and daily dose (ug/m²) (bottom) of total Modeled CO for each microenvironment (home in, home out, work in, work out, other in, other out, in vehicle) for each participant. Results are sorted by median values of the total 24-hour daily dose from highest to lowest as shown in Figure 2. Shown are medians with 25th and 75th percentiles, and whiskers for minimum and maximum values.
Figure S4. Percentage of time spent per day (%) (top) and daily dose (ug/m^2) (bottom) of total Modeled NOx for each microenvironment (home in, home out, work in, work out, other in, other out, in vehicle) for each participant. Results are sorted by median values of the total 24-hour daily dose from highest to lowest as shown in Figure 2. Shown are medians with 25th and 75th percentiles, and whiskers for minimum and maximum values.
**Figure S5.** Time spent per day (minutes) at different activity levels (light activity and all activities including light, moderate and vigorous) for each participant. Results are sorted by median values of the total 24-hour PM2.5 daily dose from highest to lowest as shown in Figure 2. Shown are medians with 25th and 75th percentiles, and whiskers for minimum and maximum values.
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