2020 National Emissions Inventory Technical Support Document: Dust – Construction - Residential

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U.S. Environmental Protection Agency
Office of Air Quality Planning and Standards
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20.1 Sector Descriptions and Overview

Construction dust refers to residential and non-residential construction activity, which are functions of acreage disturbed for construction. This sector will be divided below when describing the calculation of EPA's emissions. Table 20-1 lists the nonpoint SCCs associated with this sector in the 2020 NEI. The SCC level 1 and 2 descriptions is "Industrial Processes; Construction: SIC 15 - 17" for all SCCs.

Table 20-1: SCCs in the Construction Dust sector

SCC	SCC Level Three	SCC Level Four	TSD Section
2311010000	Residential	Total	20
2311020000	Industrial/Commercial/Institutional	Total	21
2311030000	Road Construction	Total	22

This section covers residential construction dust. Section 21 covers dust for non-residential construction activity, and Section 22 covers dust from road construction.

A list of agencies that submitted residential construction dust emissions is provided in Section 6.2.3.

20.2 EPA-developed estimates

Emissions from residential construction activity are a function of the acreage disturbed and volume of soil excavated for residential construction. Residential construction activity is developed from data obtained from the U.S. Department of Commerce (DOC)'s Bureau of the Census.

20.2.1 Activity data

There are two activity calculations performed for residential construction: acres of soil disturbed, and volume of soil removed for basements.

Determine the Number of Housing Starts in Each County

The US Census Bureau has data for *New Privately Owned Housing Units Started by Purpose and Design* [ref 1] which provides data on housing starts based on the groupings of 1 unit, 2-4 units, and 5 or more units. Regional-level results are also provided for quarterly totals and 1-unit structures in Table 20-2 [ref 1]. In order to breakdown the 2 to 4-unit category, data from a consultation with the Census Bureau in 2002 are used; approximately 1/3 of the housing starts are for 2-unit structures, and 2/3 are for 3- and 4-unit structures.

The US Census Bureau *New Privately Owned Housing Units Started by Purpose and Design* [ref 1] data for 2-4 units are distributed to two categories, 2 and 3-4 units, based on a ratio for 2 and 3-4 units calculated from the 2000 US Census Bureau *National Housing Starts* data [ref 2], for each quarter. Note that 2000 is the last full year when Census housing starts data are available separately for 2-unit and 3-4-unit homes. Table 20-3 shows a breakdown of the 2 unit and 3-4-unit structures based on the following calculation.

$$S_{Q,n} = \left(\frac{U_n}{U_t}\right) \times S_{Q,2-4} \quad (1)$$

Where:

$S_{Q,n}$ = Housing starts, by quarter, *Q*, and number of units, *n* (2 units or 3-4 units), in thousand units

U_n = Number of housing starts by number of units, *n*, from the 2000 *National Housing Starts* data, in thousand housing starts

U_t = Total number of housing starts for both 2 units and 3-4 units from the 2000 *National Housing Starts* data, in thousand housing starts

$S_{Q,2-4}$ = Number of 2-4 units by quarter, *Q*, from the *New Privately Owned Housing Units Started by Purpose and Design* data, in thousand units

Table 20-2: Housing Start Data for 2020

		Structure			Region				Regional Starts of Structures with 1 unit			
Quarter	Total	1 unit	2 to 4 units	5 units or more	NE	MW	S	W	NE	MW	S	W
Q1	328	214	3	111	29	31	186	84	12	21	127	55
Q2	299	217	3	79	22	47	157	73	13	34	120	51
Q3	387	281	3	103	32	63	203	90	19	42	154	67
Q4	363	277	3	83	29	50	191	94	17	39	153	69

Table 20-3: Breakdown of 2 to 4-unit structures

Quarter	2 to 4 units	2 units	3-4 units
Q1	3.0	1.11	1.89
Q2	3.0	1.11	1.89
Q3	3.0	1.11	1.89
Q4	3.0	1.11	1.89

Ratios of the number of 2, 3-4, and 5 or more-unit structures are then used to estimate the number of structures of each type in each region. The ratios are calculated by dividing the housing starts by quarter for each unit type by the total housing starts for buildings with 2 or more units.

$$r_{Q,n} = \frac{S_{Q,n}}{S_{Q.t}} \quad (2)$$

Where:

$r_{Q,n}$ = Ratio of structures with number of units, *n*, to total number of units by quarter, *Q*

$S_{Q,n}$ = Housing starts, by quarter, *Q*, and number of units, *n*, from distributed calculation in Step 1 for the 2-unit or 3-4 unit categories or directly from the *New Privately Owned Housing Units Started by Purpose and Design* data for the 5 units or more category, in thousand housing starts

$S_{Q,t}$ = Housing starts, by quarter, *Q*, for total number of buildings with 2 or more units, *t* (excludes 1-unit category), in thousand housing starts

The ratio is then used to distribute the *New Privately Owned Housing Units Started by Purpose and Design* regional data for all unit types to the 2, 3-4, or 5 or more-unit categories within each Census region – Northeast, Midwest, South, and West.

$$A_{Q,n,rgn} = r_{Q,n} \times (RS_{t,rgn} - RS_{1,rgn}) \quad (3)$$

Where:

$A_{Q,n,rgn}$ = Number of housing units started in quarter *Q,* by number of units*, n*, and region of the country*, rgn*, in thousand units

$r_{Q,n}$ = Ratio of structures with number of units, *n*, to total number of units by quarter, *Q*

$RS_{t,rgn}$ = Total regional starts from the *New Privately Owned Housing Units Started by Purpose and Design* data, in thousand housing starts

$RS_{1,rgn}$ = Regional starts of structures with 1 unit from the *New Privately Owned Housing Units Started by Purpose and Design* data, in thousand housing starts

Data from the Census report *New Privately Owned Housing Units Authorized Unadjusted Units* [ref 3] is used to calculate a conversion factor to determine the ratio of structures to units in the 5 or more-unit category. The conversion factor is calculated by dividing the total number of units in structures with 5 or more units by region [ref 2] by the total number of buildings with 5 or more units by region [ref 3].

$$CF_{5,rgn} = \frac{U_{5,rgn}}{B_{5,rgn}} \quad (4)$$

Where:

$CF_{5,rgn}$ = Ratio of 5 units or more to the number of buildings with 5 units or more by region, *rgn*

$U_{5,rgn}$ = Total number of 5 or more units by region, *rgn*

$B_{5,rgn}$ = Total number of buildings with 5 or more units by region, *rgn*

Structures started by category are then calculated at a regional level by summing the number of housing unit starts across all four quarters and dividing by the number of units in each building type. For the 3-4-unit type, the number of units per building is 3.5. The value is multiplied by 1,000 because the Census data are in units of thousand building starts.

For buildings with 1, 2, or 3-4 units:

$$B_{n,rgn} = \frac{(\sum_{Q1}^{Q4} A_{Q.n.rgn}) \times 1{,}000}{n} \quad (5)$$

Where:

$B_{n,rgn}$ = Number of building starts by the unit number category, *n*, and by region, *rgn*

$A_{Q,n,rgn}$ = Number of housing units started in quarter *Q,* by number of units*, n*, and region of the country*, rgn*, in thousand units

n = Number of units per building

For buildings with 5 or more units:

$$B_{n,rgn} = \frac{(\sum_{Q1}^{Q4} A_{Q.n.rgn}) \times 1{,}000}{CF_5} \quad (6)$$

Where:

$B_{n,rgn}$ = Number of building starts by the unit number category, n, and by region, rgn
$A_{Q,n,rgn}$ = Number of housing units started in quarter Q, by number of units, n, and region of the country, rgn, in thousand units
CF_5 = Ratio of 5 units or more to the number of buildings with 5 units or more

Annual county-level building permit data were obtained from the US Census Bureau [ref 4]. The County Level Residential Building Permit dataset has data to allocate regional housing starts to the county level. This results in county-level housing starts by number of units.

The number of building permits for each unit number category by region is calculated by summing the county-level Census data to the Census region level.

$$BP_{n,rgn} = \sum BP_{n,c} \quad (7)$$

Where:

$BP_{n,rgn}$ = Number of building permits by the unit number category, n, and by region, rgn
$BP_{n,c}$ = Number of building permits by the unit number category, n, and by county, c

The ratio of the number of building permits by county to the total number of building permits by region in which the county is located, for each unit number category, is then calculated.

$$R_{BP,c} = \frac{BP_{n,c}}{BP_{n,rgn}} \quad (8)$$

Where:

$R_{BP,c}$ = Ratio of building permits, BP, to total regional building permits in county c
$BP_{n,c}$ = Number of building permits by the unit number category, n, and by county, c
$BP_{n,rgn}$ = Number of building permits by the unit number category, n, and by region, rgn

The final number of building starts for each unit type category is then calculated at the county-level by multiplying the number of structures started at the regional level and the building permit ratio.

$$B_{n,c} = B_{n,rgn} \times R_{BP,c} \quad (9)$$

Where:

$B_{n,c}$ = Number of building starts by the unit number category, n, and by county, c
$B_{n,rgn}$ = Number of building starts by the unit number category, n, and by region, rgn

$R_{BP,c}$ = Ratio of building permits, *BP*, to total regional building permits in county *c*

Determine Amount of Soil Removed for Basements

To calculate basement soil removal, the *Characteristics of New Single-Family Houses Completed, Foundation table* [ref 5] is used to estimate the percentage of 1-unit structures that have a basement at the regional level. The data indicate whether the structure has a full/partial basement, slab or other type, or crawl space. However, only structures with full/partial basements are used in this calculation.

$$BM_{rgn} = \frac{BM_{fp,rgn}}{BM_{t,rgn}} \quad (10)$$

Where:

BM_{rgn} = Fraction of basements for buildings in the region
$BM_{fp,rgn}$ = Number of full or partial basements, *fp*, by region, *rgn*
$BM_{t,rgn}$ = Total number of houses regardless of basement type (full/partial, slab/other, crawl space by region, *rgn*

To estimate the number of building starts with and without basements in each county, the county level estimate of the number of 1-unit starts (from equation 9) is multiplied by the percent of 1-unit houses in the region that have a basement.

$$B_{c,BM} = B_{n.c} \times BM_{rgn} \quad (11)$$

$$B_{c,nBM} = B_{n.c} \times (1 - BM_{rgn}) \quad (11a)$$

Where:

$B_{c,BM}$ = Number of building starts by county, *c*, with a basement, *BM*
$B_{c,nBM}$ = Number of building starts by county, *c*, without a basement, *BM*
$B_{n,c}$ = Number of building starts by the unit number category, *n*, and by county, *c*
BM_{rgn} = Fraction of basements for buildings in the region

Basement volume is calculated by assuming a house with a 2000 square foot footprint has a basement dug to a depth of 8 feet (making 16,000 ft^3 per basement). An additional 10% is added for peripheral dirt bringing the total to 17,600 ft^3 (651.85 yd^3) per basement.

Determine Amount of Soil Disturbed by Unit Type

The number of acres of soil disturbed by the construction of residential buildings is calculated for apartment buildings, buildings with 2 units, and buildings with 1 unit. Table 20-4 below shows the assumptions used for the surface area disturbed for each unit type. Buildings with unit types of 3-4 and 5 or more are grouped together as apartments in this step.

Table 20-4: Surface soil removed per unit type

Structure Type	Acres disturbed
1-Unit	1/4 acre per structure
2-Unit	1/3 acre per structure
Apartment	1/2 acre per structure

For apartment buildings (sum of 3-4 and 5 or more units) and buildings with 2 units:

$$S_{n,c} = B_{n.c} \times a_n \quad (12)$$

Where:

$S_{n,c}$ = Surface soil disturbed by building construction by county, *c*, and unit type category, *n*, in acres
$B_{n,c}$ = Number of building starts by the unit type category, *n*, and by county, *c*
a_n = Acres of surface soil disturbed by each unit type category, *n*. See Table 20-4Table 20-4 for values for each type.

For buildings with 1 unit, with or without a basement:

$$S_{n,c} = B_{c,BM} \times a_n \quad (13)$$

Where:

$S_{n,c}$ = Surface soil disturbed by building construction by county, *c*, and unit type category, *n*, in acres
$B_{c,BM}$ = Number of buildings by county, *c*, with or without a basement, *BM*
a_n = Acres of surface soil disturbed by each unit type category, *n*. See Table 20-4 for values for each type.

20.2.2 Allocation procedure

Annual county building permit data were obtained from the US Census Bureau [ref 4]. The County Level Residential Building Permit dataset is used to allocate regional housing starts to the county level.

20.2.3 Emission factors

Initial PM10 emissions from construction of single family, 2-unit, and apartments structures, provided in Table 20-5, are calculated using the emissions factors [ref 5]. These emissions factors describe average "unit operations," such as "loading and unloading of earth and aggregate materials, land clearing and general vehicle traffic" [ref 6]. They therefore take into account the entire duration of construction, and not simply the duration of active excavation. The duration of construction activity for houses is assumed to be 6 months and the duration of construction for apartments is assumed to be 12 months.

Table 20-5: Emissions factors for residential construction

Type of Structure	Emissions Factor	Duration of Construction
Apartments	0.11 tons PM10/acre-month	12 months
2-Unit Structures	0.032 tons PM10/acre-month	6 months
1-unit Structures with Basements	0.011 tons PM10/acre-month	6 months
	0.059 tons PM10/1000 cubic yards	
1-Unit Structures w/o Basements	0.032 tons PM10/acre-month	6 months

To account for the soil moisture level, the PM10 emissions are weighted using the 30-year average precipitation-evaporation (PE) values from Thornthwaite's PE Index. Average precipitation evaporation

values for each state are estimated based on PE values for specific climatic divisions within a state. The average PE value for the test sites from which the PM10 emissions factor was developed is 24 [ref 6]. Equation 14 is used to adjust the county-level emissions factor based on this PE value.

To account for the silt content, the PM10-PRI emissions are weighted using average silt content for each county. EPA used the National Cooperative Soil Survey Microsoft Access Soil Characterization Database to develop county-level, average silt content values for surface soil [ref 7]. The U.S. Department of Agriculture and the National Cooperative Soil Survey define silt content of surface soil as the percentage of particles (mass basis) of diameter smaller than 50 micrometers (µm) found in the surface soil [ref 8]. Note that this definition is different than the U.S. Environmental Protection Agency's definition [ref 9] that includes all particles (mass basis) of diameter smaller than 75 micrometers. This database contains the most commonly requested data from the National Cooperative Soil Survey Laboratories including data from the Kellogg Soil Survey Laboratory and cooperating universities. The average silt content for the test sites from which the PM10 emissions factor was developed is 9% [ref 6]. Equation 7 is used to adjust the county-level emissions factor based on this silt content value.

$$AF_{PM10} = \frac{24}{PE} \times \frac{s}{9\%} \quad (14)$$

Where:

AF_{PM10} = PM10-PRI adjustment factor
PE = precipitation-evaporation value for each State
s = % dry silt content, by county, in soil for area being inventoried

This adjustment factor is used to adjust the PM10-PRI emissions factor for each unit type category – apartment, 2-unit, 1-unit with basement, and 1-unit without basement.

$$EF_{p,n,c} = AF_{PM10} \times D_n \times EF_{orig} \quad (15)$$

Where:

$EF_{p,n,c}$ = Adjusted county-level, *c*, PM10-PRI emissions factor, *p*, for each unit type category, *n*, in tons/acre
AF_{PM10} = PM10-PRI adjustment factor
D_n = Duration of construction by unit type category, *n*, in months. See Table 20-6 for duration values.
EF_{orig} = Original unadjusted PM10 emissions factor, in tons/acre. See for original emissions factors

The resulting emission factors therefore vary by county and the composite minimum, median, and maximum emission factors for these sources are provided in the "Wagon Wheel Emission Factor Compendium" on the 2020 NEI Supporting Data and Summaries site.

20.2.4 Controls

There are no controls assumed for this category.

20.2.5 Emissions

The PM10-PRI emissions are calculated by taking the sum of the surface soil disturbed by county and unit type category and multiplying it by the corresponding adjusted PM10-PRI emissions factor. Once PM10-PRI adjustments have been made, PM25-PRI emissions are estimated by applying a particle size multiplier of 0.10 to PM10-PRI emissions [ref 8]. Primary PM emissions are equal to filterable emissions since there are no condensible emissions from residential construction.

The PM10-PRI emissions are calculated at the county-level by multiplying the surface soil disturbed from construction for each unit type by the corresponding emissions factor for that unit type, and then summed across unit types.

$$E_{PM10,c} = \sum_{n=1}^{N} S_{n,c} \times EF_{PM10,n,c} \quad (1)$$

Where:

$E_{PM10,c}$ = Total PM10-PRI emissions in county *c,* in tons
$S_{n,c}$ = Surface soil disturbed by building construction by county, *c*, and unit type category, *n*
$EF_{p,n,c}$ = Adjusted county-level, *c*, PM_{10} emissions factor, *p*, for each unit type category, *n*, in tons/acre

The PM25-PRI emissions are calculated based on the assumption that they are 10% of the PM10-PRI emissions.

$$E_{PM2.5,c} = E_{PM10,c} \times 0.1 \quad (2)$$

Where:

$E_{PM2.5,c}$ = Total county-level, *c*, PM25-PRI emissions
$E_{PM10,c}$ = Total county-level, *c*, PM10-PRI emissions
0.1 = Particle size multiplier

20.2.6 Sample calculations

Table 20-6 shows sample calculations for PM10-PRI and PM25-PRI emissions from residential construction for a 2-unit structure in Suffolk County, Massachusetts. The first 3 equations use the first quarter (Q1) of 2020 for 2-unit structures as an example. However, these calculations would need to be repeated to calculate values for all 4 quarters for all 3-unit sizes. Note that structures with 5 or more units and structures with 1 unit with or without a basement have additional steps not shown in the sample calculations here.

Table 20-6: Sample calculations for PM-10 PRI and PM25-PRI emissions from residential construction of 2-unit structures

Eq. #	Equation	Values	Result
1	$S_{Q,n} = \left(\frac{U_n}{U_t}\right) \times S_{Q,2-4}$	$\left(\frac{14\ two\ unit\ housing\ starts\ in\ 2002}{38\ total\ housing\ starts\ in\ 2002}\right) \times 2\ two\ to\ four\ unit\ housing\ starts\ in\ Q1\ 2020$	0.74 thousand housing starts for 2-unit structures in Q1 2020, nationally
2	$r_{Q,n} = \frac{S_{Q,n}}{S_{Q.t}}$	$\frac{0.74\ two\ unit\ housing\ starts}{72\ two\ or\ more\ unit\ housing\ starts}$	0.01 ratio of buildings with 2 units to all 2 or more-unit housing starts for Q1 2020, nationally
3	$A_{Q,n,rgn} = r_{Q,n} \times (RS_t - RS_1)$	$0.01 \times (23\ total\ Q1\ housing\ starts\ in\ Northeast - 9\ one\ unit\ housing\ starts\ in\ Northeast\ )$	0.14 thousand housing starts for 2-unit structures for Q1 2020 in the Northeast
4	$CF_5 = \frac{U_{5,rgn}}{B_{5,r}}$	N/A	Equation is for 5 or more-unit buildings; example is for 2-unit buildings
5	$B_{n,rgn} = \frac{(\sum_{Q1}^{Q4} A_{Q.n.rgn}) \times 1{,}000}{n}$	$\frac{0.772\ two\ unit\ structures\ \times 1{,}000}{2\ units\ per\ building}$	386 2-unit structures constructed in the Northeast
6	$B_{n,rgn} = \frac{(\sum_{Q1}^{Q4} A_{Q.n.rgn}) \times 1{,}000}{CF_5}$	N/A	Equation is for 5 or more-unit buildings; example is for 2-unit buildings
7	$BP_{n,rgn} = \sum BP_{n,c}$	$\sum Northeast\ two\ unit\ building\ permits$	1,545 2-unit structure building permits in the Northeast
8	$R_{BP,c} = \frac{BP_{n,c}}{BP_{n,rgn}}$	$\frac{49\ county\ building\ permits}{1{,}545\ Northeast\ building\ permits}$	0.03172 ratio of county-level building permits to regional-level building permits

Eq. #	Equation	Values	Result
9	$B_{n,c} = B_{n,rgn} \times R_{BP,c}$	386×0.03172	12.25 total 2-unit structure building starts
10	$BM_{rgn} = \frac{BM_{fp,rgn}}{BM_{t,rgn}}$	N/A	Equation is for 1-unit buildings; example is for 2-unit buildings
11	$B_{c,BM} = B_{n.c} \times BM_{rgn}$	N/A	Equation is for 1-unit buildings; example is for 2-unit buildings
12	$S_{n,c} = B_{n.c} \times a_n$	$12.25\ two\ unit\ structures \times 0.33\ acres\ per\ structure$	4.08 acres surface soil disturbed by 2-unit structures
13	$S_{n,c} = B_{c,BM} \times a_n$	N/A	Equation is for 1-unit buildings; example is for 2-unit buildings
14	$AF_{PM10} = \frac{24}{PE} \times \frac{s}{9\%}$	$\frac{24}{119.7\ PE\ value\ for\ the\ state} \times \frac{27.07\%\ silt\ content}{9\%}$	0.603 PM10-PRI adjustment factor for 2-unit structures
15	$EF_{p,n,c} = AF_{PM10} \times D_{m,n} \times EF_{orig}$	$0.603 \times 6\ months \times 0.032\ tons\ per\ acre$	0.1158 tons/acre PM10-PRI emissions factor for 2-unit structures
16	$E_{PM10,c} = \sum S_{n,c} \times EF_{p,n,c}$	$4.08\ acres \times 0.1158\ tons\ per\ acre$	0.47 tons PM10-PRI emissions for 2-unit structures
17	$E_{PM2.5,c} = E_{PM10,c} \times 0.1$	$0.47\ tons \times 0.1$	0.047 tons PM25-PRI emissions for 2-unit structures

20.2.7 Improvements/Changes in the 2020 NEI

Except for activity data updates, there are no significant changes from the methodology used in the 2020 NEI.

20.2.8 Puerto Rico and Virgin Islands

Since insufficient data exist to calculate emissions for the counties in Puerto Rico and the US Virgin Islands, emissions are based on two proxy counties in Florida: 12011, Broward County for Puerto Rico and 12087, Monroe County for the US Virgin Islands. The total emissions in tons for these two Florida counties are divided by their respective populations creating a tons per capita emissions factor. For each Puerto Rico and US Virgin Island County, the tons per capita emissions factor is multiplied by the county population (from the same year as the inventory's activity data) which served as the activity data. In these cases, the throughput (activity data) unit and the emissions denominator unit are "EACH".

20.2.9 References

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