

INTRODUCCION

El presente documento ha sido preparado para consignar uso de metodología AP-42 de la Agencia de Protección Ambiental de los Estados Unidos de Norteamérica. Esta metodología se utilizan para evaluar el inventario de emisiones, que en promedio, emiten fuentes convencionales. Las expresiones de cálculo que se consignan en la AP-42, son resultado del estudio y evaluación empírica durante un extenso periodo de tiempo. El uso de estas expresiones de cálculo debe ser cuidadoso debido a que su aplicabilidad redundante en las características inherentes de un equipos emisor. Principalmente la metodología es utilizada para evaluar sistemas térmicos que utilizan combustibles, considerados convencionales, y cuyo uso es en combustión.

De manera general este documento cita explícitamente la metodología AP-42, no se vierten comentarios personales o concepto alguno. La metodología se utiliza como una guía, debido a que el proceso de combustión en general es propio de cada configuración de una unidad térmica.

METODOLOGÍA PARA ESTIMACIÓN DE EMISIONES PARA COMBUSTIBLES DE ORIGEN BIOMASICO UTILIZADO EN FUENTES DE COMBUSTION EXTERNAS

La metodología de cálculo consiste en obtener un factor de emisión considerando características como el combustible utilizado, el tamaño de la unidad térmica, el nivel de actividad, sistemas de control de aire y pre y pos tratamiento de los gases de combustión. Cada factor cuenta con un índice de confianza que evidencia la contundencia de mismo. El factor es tabulado según ciertas dimensiones y los datos de entrada para realizar la estimación deben ser consistentes con estos. El cálculo de la emisión esta dado por la siguiente expresión.

$$\text{Emisión} = \text{factor de emisión} * \text{grado de actividad}$$

$$E = f * G$$

Las unidades de de G pueden ser temporalmente dependientes o el valor total comprendido en un periodo de tiempo finito, y como se comento anteriormente deben poseer consistencia dimensional con el factor de emisión.

Según la emisión que se requiere calcular se debe ubicar en las tablas que a continuación se presentan los respectivos factores de emisión, de acuerdo principalmente el tamaño de la unidad térmica.

Table 1.6-1. EMISSION FACTORS FOR PM FROM WOOD RESIDUE COMBUSTION^a

Fuel	PM Control Device	Filterable PM		Filterable PM-10 ^b		Filterable PM-2.5 ^b	
		Emission Factor (lb/MMBtu)	EMISSION FACTOR RATING	Emission Factor (lb/MMBtu)	EMISSION FACTOR RATING	Emission Factor (lb/MMBtu)	EMISSION FACTOR RATING
Bark/Bark and Wet Wood	No Control ^c	0.56 ^d	C	0.50 ^e	D	0.43 ^e	D
Dry Wood	No Control ^c	0.40 ^f	A	0.36 ^e	D	0.31 ^e	D
Wet Wood	No Control ^c	0.33 ^g	A	0.29 ^e	D	0.25 ^e	D
Bark	Mechanical Collector	0.54 ^h	D	0.49 ^e	D	0.29 ^e	D
Bark and Wet Wood	Mechanical Collector	0.35 ⁱ	C	0.32 ^e	D	0.19 ^e	D
Dry Wood	Mechanical Collector	0.30 ^j	A	0.27 ^e	D	0.16 ^e	D
Wet Wood	Mechanical Collector	0.22 ^k	A	0.20 ^e	D	0.12 ^e	D
All Fuels ^m	Electrolyzed Gravel Bed	0.1 ^m	D	0.074 ^e	D	0.065 ^e	D
All Fuels ^m	Wet Scrubber	0.066 ⁿ	A	0.065 ^e	D	0.065 ^e	D
All Fuels ^m	Fabric Filter	0.1 ^o	C	0.074 ^e	D	0.065 ^e	
All Fuels ^m	Electrostatic Precipitator	0.054 ^p	B	0.04 ^e	D	0.035 ^e	
		<u>Condensable PM</u>					
All Fuels ^m	All Controls/No Controls	0.017 ^q	A				

Table 1.6-1. (cont.)

^a	Units of lb of pollutant/million Btu (MMBtu) of heat input. To convert from lb/MMBtu to lb/ton, multiply by (HHV * 2000), where HHV is the higher heating value of the fuel, MMBtu/lb. CPM = Condensible Particulate Matter. These factors apply to Source Classification Codes (SCC) 1-0X-009-YY, where X = 1 for utilities, 2 for industrial, and 3 for commercial/institutional, and where Y = 01 for bark-fired boiler, 02 for bark and wet wood-fired boiler, 03 for wet wood-fired boiler, and 08 for dry wood-fired boiler.
^b	PM-10 = particulate matter less than or equal to 10 microns in aerodynamic diameter. PM-2.5 = particulate matter less than or equal to 2.5 microns in aerodynamic diameter. Filterable PM = PM captured and measured on the filter in an EPA Method 5 (or equivalent) sampling train. Condensible PM = PM captured and measured in an EPA Method 202 (or equivalent) sampling train.
^c	Factor represents boilers with no controls, Breslove separators, Breslove separators with reinjection, and mechanical collectors with reinjection. Mechanical collectors include cyclones and multiclones.
^d	References 19-21, 88.
^e	Cumulative mass % provided in Table 1.6-6 for Bark and Wet Wood-fired boilers multiplied by the Filterable PM factor.
^f	References 22-32, 88.
^g	References 26, 33-36, 88.
^h	References 37, 38, 88.
ⁱ	References 26, 39-41, 88.
^j	References 26, 27, 34, 42-54, 88.
^k	Reference 55-57, 88.
^l	All fuels = Bark, Bark and Wet Wood, Dry Wood, and Wet Wood.
^m	References 27, 58, 88.
ⁿ	References 26, 59-66, 88.
^o	References 26, 67-70, 88.
^p	References 26, 71-74, 88.
^q	References 19-21, 25, 28, 29, 31, 32, 36-41, 46, 51, 53-60, 62 - 65, 67-69, 72-75, 88.

Table 1.6-2. EMISSION FACTORS FOR NO_x, SO₂, AND CO FROM WOOD RESIDUE COMBUSTION^a

Source Category ^c	NO _x ^b		SO ₂ ^b		CO ^b	
	Emission Factor (lb/MMBtu)	EMISSION FACTOR RATING	Emission Factor (lb/MMBtu)	EMISSION FACTOR RATING	Emission Factor (lb/MMBtu)	EMISSION FACTOR RATING
Bark/bark and wet wood/wet wood-fired boiler	0.22 ^d	A	0.025 ^e	A	0.60 ^{f,g,i,j}	A
Dry wood-fired boilers	0.49 ^h	C	0.025 ^e	A	0.60 ^{f,g,i,j}	A

^a Units of lb of pollutant/million Btu (MMBtu) of heat input. To convert from lb/MMBtu to lb/ton, multiply by (HHV * 2000), where HHV is the higher heating value of the fuel, MMBtu/lb. To convert lb/MMBtu to kg/J, multiply by 4.3E-10. NO_x = Nitrogen oxides, SO₂ = Sulfur dioxide, CO = Carbon monoxide.

^b Factors represent boilers with no controls or with particulate matter controls.

^c These factors apply to Source Classification Codes (SCC) 1-0X-009-YY, where X = 1 for utilities, 2 for industrial, and 3 for commercial/institutional, and where Y = 01 for bark-fired boiler, 02 for bark and wet wood-fired boiler, 03 for wet wood-fired boiler, and 08 for dry wood-fired boiler.

^d References 19, 33, 34, 39, 40, 41, 55, 62-64, 67, 70, 72, 78, 79, 88-89.

^e References 26, 45, 50, 72, 88-89.

^f References 26, 59, 88-89.

^g References 19, 26, 39-41, 60-64, 67, 68, 70, 75, 79, 88-89.

^h References 30, 34, 45, 50, 80, 81, 88-89.

ⁱ References 26, 30, 45-51, 80-82, 88-89.

^j Emission factor is for stokers and dutch ovens/fuel cells. References 26, 34, 36, 55, 60, 65, 71, 72, 75. **CO Factor for fluidized bed combustors is 0.17 lb/MMBtu.** References 26, 72, 88-89.

Table 1.6-3. EMISSION FACTORS FOR SPECIATED ORGANIC COMPOUNDS, TOC, VOC, NITROUS OXIDE, AND CARBON DIOXIDE FROM WOOD RESIDUE COMBUSTION^a

Organic Compound	Average Emission Factor ^b (lb/MMBtu)	EMISSION FACTOR RATING
Acenaphthene	9.1 E-07 ^c	B
Acenaphthylene	5.0 E-06 ^d	A
Acetaldehyde	8.3 E-04 ^e	A
Acetone	1.9 E-04 ^f	D
Acetophenone	3.2 E-09 ^g	D
Acrolein	4.0 E-03 ^h	C
Anthracene	3.0 E-06 ⁱ	A
Benzaldehyde	<8.5 E-07 ^j	D
Benzene	4.2 E-03 ^k	A
Benzo(a)anthracene	6.5 E-08 ^l	B
Benzo(a)pyrene	2.6 E-06 ^m	A
Benzo(b)fluoranthene	1.0 E-07 ^l	B
Benzo(e)pyrene	2.6 E-09 ^f	D
Benzo(g,h,i)perylene	9.3 E-08 ⁿ	B
Benzo(j,k)fluoranthene	1.6 E-07 ^o	D
Benzo(k)fluoranthene	3.6 E-08 ^p	B
Benzoic acid	4.7 E-08 ^q	D
bis(2-Ethylhexyl)phthalate	4.7 E-08 ^g	D
Bromomethane	1.5 E-05 ^f	D
2-Butanone (MEK)	5.4 E-06 ^f	D
Carbazole	1.8 E-06 ^f	D
Carbon tetrachloride	4.5 E-05 ^r	D
Chlorine	7.9 E-04 ^s	D
Chlorobenzene	3.3 E-05 ^f	D
Chloroform	2.8 E-05 ^f	D
Chloromethane	2.3 E-05 ^f	D
2-Chloronaphthalene	2.4 E-09 ^f	D
2-Chlorophenol	2.4 E-08 ^u	C
Chrysene	3.8 E-08 ^c	B
Crotonaldehyde	9.9 E-06 ^j	D
Decachlorobiphenyl	2.7 E-10 ^r	D
Dibenzo(a,h)anthracene	9.1 E-09 ^l	B
1,2-Dibromoethene	5.5 E-05 ^f	D
Dichlorobiphenyl	7.4 E-10 ^r	C
1,2-Dichloroethane	2.9 E-05 ^r	D
Dichloromethane	2.9 E-04 ^v	D
1,2-Dichloropropane	3.3 E-05 ^f	D
2,4-Dinitrophenol	1.8 E-07 ^w	C
Ethylbenzene	3.1 E-05 ^f	D
Fluoranthene	1.6 E-06 ^x	B
Fluorene	3.4 E-06 ⁱ	A
Formaldehyde	4.4 E-03 ^y	A
Heptachlorobiphenyl	6.6E-11 ^r	D

Table 1.6-3. (cont.)

Organic Compound	Average Emission Factor ^b (lb/MMBtu)	EMISSION FACTOR RATING
Hexachlorobiphenyl	5.5 E-10 ^r	D
Hexanal	7.0 E-06 ^z	D
Heptachlorodibenzo-p-dioxins	2.0 E-09 ^{aa}	C
Heptachlorodibenzo-p-furans	2.4 E-10 ^{aa}	C
Hexachlorodibenzo-p-dioxins	1.6 E-06 ^{aa}	C
Hexachlorodibenzo-p-furans	2.8 E-10 ^{aa}	C
Hydrogen chloride	1.9 E-02 ^j	C
Indeno(1,2,3,c,d)pyrene	8.7 E-08 ^l	B
Isobutyraldehyde	1.2 E-05 ^z	D
Methane	2.1 E-02 ^f	C
2-Methylnaphthalene	1.6 E-07 ^z	D
Monochlorobiphenyl	2.2 E-10 ^r	D
Naphthalene	9.7 E-05 ^{ab}	A
2-Nitrophenol	2.4 E-07 ^w	C
4-Nitrophenol	1.1 E-07 ^w	C
Octachlorodibenzo-p-dioxins	6.6 E-08 ^{aa}	B
Octachlorodibenzo-p-furans	8.8 E-11 ^{aa}	C
Pentachlorodibenzo-p-dioxins	1.5 E-09 ^{aa}	B
Pentachlorodibenzo-p-furans	4.2 E-10 ^{aa}	C
Pentachlorobiphenyl	1.2 E-09 ^r	D
Pentachlorophenol	5.1 E-08 ^{ac}	C
Perylene	5.2 E-10 ^f	D
Phenanthrene	7.0 E-06 ^{ad}	B
Phenol	5.1 E-05 ^{ae}	C
Propanal	3.2 E-06 ^z	D
Propionaldehyde	6.1 E-05 ^f	D
Pyrene	3.7 E-06 ^{af}	A
Styrene	1.9 E-03 ^f	D
2,3,7,8-Tetrachlorodibenzo-p-dioxins	8.6 E-12 ^{aa}	C
Tetrachlorodibenzo-p-dioxins	4.7 E-10 ^{ag}	C
2,3,7,8-Tetrachlorodibenzo-p-furans	9.0 E-11 ^{aa}	C
Tetrachlorodibenzo-p-furans	7.5 E-10 ^{aa}	C
Tetrachlorobiphenyl	2.5 E-09 ^r	D
Tetrachloroethene	3.8 E-05 ^t	D
o-Tolualdehyde	7.2 E-06 ^j	D
p-Tolualdehyde	1.1 E-05 ^z	D
Toluene	9.2 E-04 ^v	C
Trichlorobiphenyl	2.6 E-09 ^r	C
1,1,1-Trichloroethane	3.1 E-05 ^t	D
Trichloroethene	3.0 E-05 ^t	D
Trichlorofluoromethane	4.1 E-05	D
2,4,6-Trichlorophenol	<2.2 E-08 ^{ak}	C

Table 1.6-3. (cont.)

Organic Compound	Average Emission Factor ^b (lb/MMBtu)	EMISSION FACTOR RATING
Vinyl Chloride	1.8 E-05^r	D
o-Xylene	2.5 E-05^v	D
Total organic compounds (TOC)	0.039^{ai}	D
Volatile organic compounds (VOC)	0.017^{aj}	D
Nitrous Oxide (N ₂ O)	0.013^{ak}	D
Carbon Dioxide (CO ₂)	195^{al}	A

^a Units of lb of pollutant/million Btu (MMBtu) of heat input. To convert from lb/MMBtu to lb/ton, multiply by (HHV * 2000), where HHV is the higher heating value of the fuel, MMBtu/lb. To convert lb/MMBtu to kg/J, multiply by 4.3E-10. These factors apply to Source Classification Codes (SCC) 1-0X-009-YY, where X = 1 for utilities, 2 for industrial, and 3 for commercial/institutional, and where Y = 01 for bark-fired boiler, 02 for bark and wet wood-fired boiler, 03 for wet wood-fired boiler, and 08 for dry wood-fired boiler.

^b Factors are for boilers with no controls or with particulate matter controls.

^c References 26, 34, 36, 59, 60, 65, 71-73, 75.

^d References 26, 33, 34, 36, 59, 60, 65, 71-73, 75.

^e References 26, 35, 36, 46, 50, 59, 60, 65, 71-75.

^f Reference 26.

^g Reference 33.

^h Reference 26, 50, 83.

ⁱ References 26, 34, 36, 59, 60, 65, 71-73, 75.

^j References 26, 50.

^k References 26, 35, 36, 46, 59, 60, 65, 70, 71-75.

^l References 26, 36, 59, 60, 65, 70-75.

^m References 26, 33, 36, 59, 60, 65, 70-73, 75.

ⁿ References 26, 33, 36, 59, 60, 65, 71-73, 75.

^o Reference 34.

^p References 26, 36, 60, 65, 71-75.

^q References 26, 33.

^r References 26.

^s Reference 83.

^t References 26, 72.

^u References 35, 60, 65, 71, 72.

^v References 26, 72.

^w References 35, 60, 65, 71, 72.

^x References 26, 33, 34, 59, 60, 65, 71-75.

^y References 26, 28, 35, 36, 46 - 51, 59, 60, 65, 70, 71-75, 79, 81, 82.

^z Reference 50.

^{aa} Reference 26, 45.

^{ab} References 26, 33, 34, 36, 59, 60, 65, 71-75, 83.

^{ac} References 26, 35, 60, 65, 71, 72.

^{ad} References 26, 33, 34, 36, 59, 60, 65, 71 - 73.

^{ae} References 26, 33, 34, 35, 60, 65, 70, 71, 72.

^{af} References 26, 33, 34, 36, 59, 60, 65, 71 - 73, 83.

^{ag} References 26, 45.

^{ah} References 26, 35, 60, 65, 71.

^{ai} TOC = total organic compounds. Factor is the sum of all factors in table except nitrous oxide and carbon dioxide.

^{aj} VOC volatile organic compounds. Factor is the sum of all factors in table except hydrogen chloride, chlorine, formaldehyde, tetrachloroethene, 1,1,1-trichloroethane, dichloromethane, acetone, nitrous oxide, methane, and carbon dioxide.

^{ak} Reference 83.

^{al} References 19 - 26, 33 - 49, 51- 57, 77, 79 - 82, 84 - 86.

**Table 1.6-4. EMISSION FACTORS FOR TRACE ELEMENTS
FROM WOOD RESIDUE COMBUSTION^a**

Trace Element	Average Emission Factor (lb/MMBtu) ^b	EMISSION FACTOR RATING
Antimony	7.9 E-06^c	C
Arsenic	2.2 E-05^d	A
Barium	1.7 E-04^c	C
Beryllium	1.1 E-06^e	B
Cadmium	4.1 E-06^f	A
Chromium, total	2.1 E-05^g	A
Chromium, hexavalent	3.5 E-06^h	C
Cobalt	6.5 E-06ⁱ	C
Copper	4.9 E-05^g	A
Iron	9.9 E-04^k	C
Lead	4.8 E-05^l	A
Manganese	1.6 E-03^d	A
Mercury	3.5 E-06^m	A
Molybdenum	2.1 E-06^c	D
Nickel	3.3 E-05ⁿ	A
Phosphorus	2.7 E-05^c	D
Potassium	3.9 E-02^c	D
Selenium	2.8 E-06^o	A
Silver	1.7 E-03^p	D
Sodium	3.6 E-04^c	D
Strontium	1.0 E-05^c	D
Tin	2.3 E-05^c	D
Titanium	2.0 E-05^c	D
Vanadium	9.8 E-07^c	D
Yttrium	3.0 E-07^c	D
Zinc	4.2 E-04^o	A

^a Units of lb of pollutant/million Btu (MMBtu) of heat input. To convert from lb/MMBtu to lb/ton, multiply by (HHV * 2000), where HHV is the higher heating value of the fuel, MMBtu/lb. To convert lb/MMBtu to kg/J, multiply by 4.3E-10. These factors apply to Source Classification Codes (SCC) 1-0X-009-YY, where X = 1 for utilities, 2 for industrial, and 3 for commercial/institutional, and where Y = 01 for bark-fired boiler, 02 for bark and wet wood-fired boiler, 03 for wet wood-fired boiler, and 08 for dry wood-fired boiler.

^b Factors are for boilers with no controls or with particulate matter controls.

^c Reference 26.

^d References 26, 33, 36, 46, 59, 60, 65, 71-73, 75, 81.

^e References 26, 35, 36, 46, 59, 60, 65, 71-73, 75.

^f References 26, 35, 36, 42, 46, 59, 60, 65, 71-73, 75, 81.

^g References 26, 34, 35, 36, 42, 59, 60, 65, 71-73, 75, 81.

^h References 26, 36, 46, 59, 60, 71, 72, 73, 75.

ⁱ References 26, 34, 83.

^j References 26, 33-36, 46, 59, 60, 65, 71-73, 75, 81.

^k References 26, 71, 72, 81.

^l References 26, 33-36, 46, 59, 60, 65, 71-73, 75.

^m References 26, 35, 36, 46, 59, 60, 65, 71-73, 75, 81.

ⁿ References 26, 33 - 36, 46, 59, 60, 65, 71-73, 75, 81.

^o References 26, 33, 35, 46, 59, 60, 65, 71-73, 75, 81.

^p Reference 34.

Table 1.6-5. CUMULATIVE PARTICLE SIZE DISTRIBUTION AND SIZE-SPECIFIC EMISSION FACTORS FOR WOOD/BARK-FIRED BOILERS^a

EMISSION FACTOR RATING: E

Particle Size ^b (µm)	Cumulative Mass % ≤ Stated Size				
	Uncontrolled ^c	Controlled			Dry Electrostatic Granular Filter (DEGF)
		Multiple Cyclone ^d	Multiple Cyclone ^e	Scrubber ^f	
15	94	96	35	98	77
10	90	91	32	98	74
6	86	80	27	98	69
2.5	76	54	16	98	65
1.25	69	30	8	96	61
1.00	67	24	6	95	58
0.625	ND	16	3	ND	51
Total	100	100	100	100	100

^a Reference 89.

^b Expressed as aerodynamic equivalent diameter.

^c From data on underfeed stokers. May also be used as size distribution for wood-fired boilers.

^d From data on spreader stokers with flyash reinjection.

^e From data on spreader stokers without flyash reinjection.

^f From data on Dutch ovens. Assumed control efficiency is 94%.