Appendix 4B

Portable Fuel Container Emission Estimates for 2005

Excerpted from

CTDEP's Draft 2005 Periodic Emissions Inventory

(draft dated April 16, 2007)

4.6.14 Portable Fuel Containers (Gas-Cans)

The activity and Uncontrolled VOC emissions from portable fuel containers are presented in Tables 4.6.14-1 through 4.6.14-3. Controlled VOC emissions are presented in Table 4.6.14-4. Emissions were estimated following the methodology outlined in the California's Air Resource Board's "Notice of Public Meeting to Consider the Approval of California's Portable Gasoline-Container Emissions Inventory"[37]. Portable fuel containers or gas-cans have five different emission modes: permeation and diurnal (associated with storage), transport-spillage (associated with filling the gas-can), refueling spillage and refueling-vapor displacement (associated with equipment refueling). The emissions associated with equipment refueling are already estimated by the EPA's non-road model and are included in the non-road portion of the inventory. The emissions from gas-cans associated with filling the gas-can and storage were not estimated in previous Periodic Emission Inventories.

Emission estimates were made depending on how the gas-can was stored (open or closed), what material the gas-can was made of (metal or plastic) and whether the gas-can was used by a homeowner (residential) or a business (commercial). A gas can is considered open when it is stored with an open breathing hole or an uncapped nozzle. A closed system exists when the breathing hole is closed and the nozzle is capped. Emissions were calculated separately for residential and commercial use, because the profile of gas-cans and their usage differ. For example the average residential and commercial gas-can capacity is 2.34 and 3.43 gallons, respectively.

Residential Gas-Cans.

The following equation was used to calculate the residential gas-can population for each county in Connecticut:

$$Pop_R = (N)(A)(CountR)$$

Where:

Pop_R = number of residential gas-cans,
N = number of occupied housing units by county in CT,
A = percentage of households with gas-cans (46%),
$Count_R$ = average number of residential gas-cans per household (1.8).

A sample calculation of the number of residential gas-cans in Fairfield County in 2005 is as follows:

$$Pop_R = (324,735)(0.46)(1.8)$$

$$Pop_R = 268,881 \text{ gas-cans}$$

Permeation emissions are produced after fuel has been stored long enough in a can for fuel to infiltrate and saturate the can material.

The following equation was used to calculate the uncontrolled permeation emissions from residential gas-cans:

$$HC_{PR} = Pop_R \times S \times EF_P \times B_R \times Size_R \times Level \times CF$$

Where:

HC_{PR} = permeation emissions in pounds per day,
Pop_R = residential gas-can population,
EF_P = appropriate permeation emission factor with respect to material (plastic 1.57 g/gal-day; metal 0.06 g/gal-day),
S = percentage of gas-cans stored with fuel (70%),
B_R = percentage of cans stored in closed condition with respect to material (plastic 53%; metal 13%),
$Size_R$ = weighted average capacity of residential gas-cans (2.34 gallons),
Level = weighted average amount of stored fuel (49%),
CF = conversion factor 0.002205 pounds per gram.

A sample calculation estimating the uncontrolled permeation emissions from plastic residential gas-cans in Fairfield County is as follows:

$$HC_{PR(PLASTIC)} = 268{,}881 \times 0.70 \times 1.57 \times 0.53 \times 2.34 \times 0.49 \times 0.002205$$

$$HC_{PR(PLASTIC)} = 396 \text{ pounds per day}$$

A sample calculation estimating the uncontrolled permeation emissions from metal residential gas-cans in Fairfield County is as follows:

$$HC_{PR(METAL)} = 268{,}881 \times 0.70 \times 0.06 \times 0.13 \times 2.34 \times 0.49 \times 0.002205$$

$$HC_{PR(METAL)} = 4 \text{ pounds per day}$$

Total uncontrolled permeation emissions from plastic and metal residential gas- cans in Fairfield County is as follows:

$$HC_{PR} = 396 + 4$$

$$HC_{PR} = 400 \text{ pounds of VOC per day.}$$

Diurnal emissions result when stored fuel vapors escape to the ambient air through openings while the gas-can is subjected to the daily cycle of increasing and decreasing ambient temperatures. Diurnal emissions vary depending on a number of factors including the material the gas-can is made of, and

whether the gas can is properly sealed (i.e. whether or not the vents, breathing holes or nozzle are tightly closed on the gas-can).

Uncontrolled diurnal emissions from both open and closed residential gas-cans were calculated as follows:

$$HC_{DR} = Pop_R \times S \times EF_D \times B_R \times Size_R \times Level \times CF$$

Where:

HC_{DR} = uncontrolled diurnal emissions expressed in pounds per day for residential gas-cans with respect to storage condition (open or closed) and material (plastic or metal),
Pop_R = statewide residential gas-can population,
S = percentage of gas-can population stored with fuel (70%),
EF_D = appropriate diurnal emission factor with respect to storage condition and material (closed plastic 1.38 g/gal-day; closed metal 0.44 g/gal-day; or open 21.8 g/day applies for both metal or plastic),
B_R = percentage of gas-can population with respect to storage condition and material (plastic open 23%, closed 53%; metal open 11%, closed 13%),
$Size_R$ = weighted average capacity of residential gas-cans (2.34 gal.),
Level = weighted average amount of stored fuel (49%),
CF = conversion factor 0.002205 pounds per gram.

A sample calculation estimating uncontrolled diurnal emissions from properly closed plastic residential gas-cans in Fairfield County is as follows:

$$HC_{DR(PLASTIC)} = 268{,}881 \times 0.7 \times 1.38 \times 0.53 \times 2.34 \times 0.49 \times 0.002205$$

$HC_{DR(PLASTIC)}$ = 348 pounds of VOC per day

A sample calculation estimating uncontrolled diurnal emissions from properly closed metal residential gas-cans in Fairfield County is as follows:

$$HC_{DR(METAL)} = 268{,}881 \times 0.7 \times 0.44 \times 0.13 \times 2.34 \times 0.49 \times 0.002205$$

$HC_{DR(METAL)}$ = 27 pounds of VOC per day

A sample calculation estimating uncontrolled diurnal emissions from open residential gas-cans in Fairfield County is as follows:

$HC_{DR(OPEN)}$ = 268,881 x 0.7 x 21.8 x 0.34 x 0.002205

$HC_{DR(OPEN)}$ = 3,076 pounds of VOC per day.

Total uncontrolled diurnal emissions from open and closed residential gas-cans in Fairfield County is as follows:

HC_{DR} = 348+ 27 +3,076

HC_{DR} = 3,451 pounds of VOC per day.

Transport-spillage emissions arise when fuel escapes (e.g. spill, etc.) from gas-cans while in transit.

The uncontrolled emissions from the transport-spillage of residential gas-cans were determine using the following equation:

$HC_{TR} = Pop_R \times S \times Refill_R \times EF_T \times B_R \times CF$

Where:

HC_{TR} =uncontrolled residential gas-can transport spillage emissions, expressed in pounds per day
Pop_R =statewide residential gas-can population
S =percentage of gas-cans stored with fuel (70%)
$Refill_R$ = average number of residential gas-cans-pump-refills per day per can (0.0174 gas-can refill/day)
EF_T =transport emission factor with respect to storage condition; 23.0 grams per gas-can refill (g/refill) for a closed gas-can, and 32.5 g/refill for an open gas can)
B_R =percentage of gas-cans with respect to storage condition (open 34%, and closed 66%),
CF =conversion factor 0.002205 pounds per gram.

A sample calculation estimating uncontrolled transport-spillage emissions from properly closed residential gas-cans in Fairfield County is as follows:

$HC_{TR(CLOSED)}$ = 268,881 x 0.7 x 0.0174 x 23.0 x 0.66 x 0.002205

$HC_{TR(CLOSED)}$ = 110 pounds of VOC per day

A sample calculation estimating uncontrolled transport-spillage emissions from open residential gas-cans in Fairfield County is as follows:

$HC_{TR(OPEN)}$ = 268,881 x 0.7 x 0.0174 x 32.5 x 0.34 x 0.002205

$HC_{TR(OPEN)}$ = 80 pounds of VOC per day.

Total uncontrolled transport-spillage emissions from plastic and metal residential gas- cans in Fairfield County is as follows:

HC_{DR} = 110 + 80

HC_{DR} = 190 pounds of VOC per day.

Commercial Gas-Cans.

Businesses identified by the following North American Industrial Classification System (NAICS) were assumed to have at least one gas-can: 111, 112, 113,114*, 115, 23, 311119, 326212, 4411, 447, 452990, 488410, 5321, 541320, 541620, 541690, 81111 and 812930[38]. This list was provided by Judy Rand of the New Jersey Department of Environmental Protection, which is an adaptation of the Standard Industrial Classification (SICs) listed on page 9 of the Pechan report titled "Control Measure Development Support Analysis of Ozone Transport Commission Model Rules"[36]. The NAICs list includes fishing and landscaping which did not appear in the Pechan SIC list.

The Connecticut DOL provided the number of businesses by county that fall under any of the aforementioned NAICS[39]. To determine the emissions from commercially used gas-cans the commercial gas-can population was calculated as follows:

$$Pop_C = (N_C)(Count_C)(A)$$

Where:

Pop_C =statewide commercial gas-can population,
N_C =number of occupied businesses in each county,
$Count_C$ = average number of gas-cans per business (6.9)
A =percentage of businesses with gas-cans (80%).

A sample calculation of the number of commercial gas-cans in Fairfield County in 2005 is as follows:

Pop_C = (3,868)(6.9)(.80)

Pop_C = 21,351 gas-cans

The following equation was used to calculate the uncontrolled permeation emissions from commercial gas-cans:

$$HC_{PC} = Pop_C \times S \times EF_P \times B_C \times Size_C \times Level \times CF$$

Where:

HC_{PC} = uncontrolled permeation Emissions in pounds per day,
Pop_C = residential gas-can population,
EF_P = appropriate permeation emission factor with respect to material (plastic 1.57 g/gal-day; metal 0.06 g/gal-day),
S = percentage of gas-cans stored with fuel (70%),
B_C = percentage of cans stored in closed condition with respect to material (plastic 33%; metal 18%),
$Size_C$ = weighted average capacity of residential gas-cans (3.43 gallons),
Level = weighted average amount of stored fuel (49%),
CF = conversion factor 0.002205 pounds per gram.

A sample calculation estimating the uncontrolled permeation emissions from plastic commercial gas-cans in Fairfield County is as follows:

$$HC_{PC(PLASTIC)} = 21{,}351 \times 0.70 \times 1.57 \times 0.33 \times 3.43 \times 0.49 \times 0.002205$$

$$HC_{PC(PLASTIC)} = 29 \text{ pounds per day}$$

A sample calculation estimating the uncontrolled permeation emissions from metal commercial gas-cans in Fairfield County is as follows:

$$HC_{PC(METAL)} = 21{,}351 \times 0.70 \times 0.06 \times 0.18 \times 3.43 \times 0.49 \times 0.002205$$

$$HC_{PC(METAL)} = 1 \text{ pounds per day}$$

Total uncontrolled permeation emissions from plastic and metal residential gas- cans in Fairfield County is as follows:

$$HC_{PC} = 29 + 1$$

$$HC_{PC} = 30 \text{ pounds of VOC per day.}$$

Uncontrolled diurnal emissions from both open and closed commercial gas-cans were calculated as follows:

$$HC_{DC} = Pop_C \times S \times EF_D \times B_C \times Size_C \times Level \times CF$$

Where:

HC_{DC} = uncontrolled diurnal emissions expressed in pounds per day for commercial gas-cans with respect to storage condition (open or closed) and material (plastic or metal),
Pop_C = statewide commercial gas-can population,
S = percentage of gas-can population stored with fuel (70%),
EF_D = appropriate diurnal emission factor with respect to storage condition and material (closed plastic 1.38 g/gal-day; closed metal 0.44 g/gal-day; or open 21.8 g/day applies for both metal or plastic),
B_C = percentage of gas-can population with respect to storage condition and material (plastic open 39%, closed 33%; metal open 10%, closed 18%),
$Size_C$ = weighted average capacity of commercial gas-cans (3.43 gal.),
Level = weighted average amount of stored fuel (49%),
CF = conversion factor 0.002205 pounds per gram.

A sample calculation estimating uncontrolled diurnal emissions from properly closed plastic commercial gas-cans in Fairfield County is as follows:

$$HC_{DC(PLASTIC)} = 21{,}351 \times 0.7 \times 1.38 \times 0.33 \times 3.43 \times 0.49 \times 0.002205$$

$$HC_{DC(PLASTIC)} = 25 \text{ pounds of VOC per day}$$

A sample calculation estimating uncontrolled diurnal emissions from properly closed metal commercial gas-cans in Fairfield County is as follows:

$$HC_{DC(METAL)} = 21{,}351 \times 0.7 \times 0.44 \times 0.18 \times 3.43 \times 0.49 \times 0.002205$$

$$HC_{DC(METAL)} = 4 \text{ pounds of VOC per day}$$

A sample calculation estimating uncontrolled diurnal emissions from an open commercial gas-cans in Fairfield County is as follows:

$$HC_{DC(OPEN)} = 21{,}351 \times 0.7 \times 21.8 \times 0.49 \times 0.002205$$

$$HC_{DC(OPEN)} = 352 \text{ pounds of VOC per day}$$

Total uncontrolled diurnal emissions from open and closed residential gas-cans in Fairfield County is as

follows:

HC_{DC} = 25+ 4 +352

HC_{DC} = 381 pounds of VOC per day.

Transport-spillage emissions factors for commercial gas-cans are expected to be the same as those for residential gas-cans: 23.0 g/refill per can for a closed container, and 32.5 g/refill per can for an open container. The refueling of gas-cans used for commercial lawn and garden equipment occurs much more frequently than gas-cans used to refuel other commercial equipment. In fact the frequency of gas-cans used for the refueling of commercial lawn and garden equipment are estimated to occur 0.964 times per day while gas-cans used for non-lawn and garden commercial equipment are estimated to be refilled only 0.12 times per day.[37] For this reason the differences in refilling activity between commercial lawn and garden equipment, and non-lawn and garden equipment were accounted for when estimating transport-spillage emissions.

All businesses associated with NAICS 541320 "Landscape Architectural Services" were assumed to operate commercial lawn and garden equipment. All other businesses were not. Table 4.6.14-1 contains the number of gas-cans per county that were assumed to refuel commercial lawn and garden equipment.

The uncontrolled emissions from the transport-spillage of commercial gas-cans were determine using the following equation:

$$HC_{TC} = Pop_C \times S \times Refill_C \times EF_T \times B_C \times CF$$

Where:

HC_{TC} =uncontrolled commercial gas-can transport spillage emissions, expressed in pounds per day

Pop_C =gas-can population used to refuel commercial lawn and garden equipment or non-lawn and garden equipment

S =percentage of gas-cans stored with fuel (70%)

$Refill_C$ = average number of commercial gas-cans-pump-refills per day per can (0.964 refill/day for commercial lawn and garden equipment or 0.12 refill/day for non-lawn and garden commercial equipment)

EF_T =transport emission factor with respect to storage condition; 23.0 grams per gas-can refill (g/refill) for a closed gas-can, and 32.5 g/refill for an open gas can)

B_C =percentage of gas-cans with respect to storage condition (open 49%, and closed 51%),

CF =conversion factor 0.002205 pounds per gram.

A sample calculation estimating uncontrolled transport-spillage emissions from properly closed gas-cans used to refuel commercial lawn and garden equipment in Fairfield County is as follows:

$HC_{TC(LawnClosed)}$ = 270 x 0.7 x 0.964 x 23.0 x 0.51 x 0.002205

$HC_{TC(LawnClosed)}$ = 5 pounds per day

A sample calculation estimating uncontrolled transport-spillage emissions from open gas-cans used to refuel commercial lawn and garden equipment in Fairfield County is as follows:

$HC_{TC(LawnOpen)}$ = 270 x 0.7 x 0.964 x 32.5 x 0.49 x 0.002205

$HC_{TC(LawnOpen)}$ = 6 pounds per day

A sample calculation estimating uncontrolled transport-spillage emissions from properly closed gas-cans used to refuel commercial **non**-lawn and garden equipment in Fairfield County is as follows:

$HC_{TC(Non-LawnClosed)}$ = 21,081 x 0.7 x 0.12 x 23.0 x 0.51 x 0.002205

$HC_{TC(Non-LawnClosed)}$ = 46 pounds per day

A sample calculation estimating uncontrolled transport-spillage emissions from an open gas-cans used to refuel commercial **non**-lawn and garden equipment in Fairfield County is as follows:

$HC_{TC(Non-LawnOpen)}$ = 21,081 x 0.7 x 0.12 x 32.5 x 0.49 x 0.002205

$HC_{TC(Non-LawnOpen)}$ = 62 pounds per day

Total uncontrolled transport-spillage emissions from all commercial gas-cans in Fairfield County is as follows:

HC_{TC} = 5+ 6 + 46+62

HC_{TC} = 119 pounds of VOC per day.

Total Controlled Emissions.

Recently Connecticut adopted a new regulation (Section 22a-174-43) which s requires portable fuel containers and spouts sold on or after May 1, 2004 to meet specified permeation and fuel flow rates and to have automatic shut-offs to prevent tank overflows during refueling. The regulation includes a pass through provision allowing units manufactured prior to May 1, 2004 to be sold through May 1, 2005. In addition, the regulation specifies labeling requirements and test procedures to be used by manufacturers to demonstrate product compliance.

Connecticut's regulation regarding portable fuel containers has equivalent requirements to those specified in the model rule developed by the Ozone Transport Commission (OTC). An analysis done by the OTC, assuming 80% rule effectiveness, estimates that the new regulation will reduce VOC emissions from portable fuel containers by 6.82 percent in Connecticut in 2005.

The total controlled area source portable fuel container emissions are summed as follows:

$$Ep_S = (HC_{PR} + HC_{DR} + HC_{TR} + HC_{PC} + HC_{DC} + HC_{TC}) \times (1\text{-}\%CNTRL)$$

Where:

Ep_S = typical after controls summer day emissions from all residential and commercial gas-cans, expressed in pounds per day,

%CNTRL = Connecticut's portable fuel container regulation is estimated to reduce uncontrolled emissions by 6.82% in 2005.

Total controlled VOC emissions from all residential and commercial gas-cans on a typical summer day in Fairfield County is as follows:

$$Ep_S = (400 + 3{,}451 + 190 + 30 + 381 + 119) \times (1 - 0.0682)$$

Ep_S = 4,259 pounds of VOC per day.

According to EPA's "Estimating Emissions Associated with Portable Fuel Containers (PFCs)"[40], 38 percent of the number of portable fuel container refills occurs in the summer.

Annual emissions were calculated using the following equation:

$$Ep_A = \frac{Ep_S \times Days \times Weeks}{SAF \times 2{,}000}$$

Where:

Ep_A =annual emissions expressed in tons per year,
Days =days per week activity occurs (7 days),
Weeks =weeks per summer activity occurs (13),
SAF =percent activity that occurs in the summer (38%)
2,000 =conversion factor 2,000 pounds per ton.

Total annual controlled VOC emissions from all residential and commercial gas-cans in Fairfield County is as follows:

$$Ep_A = \frac{4{,}259 \text{ x } 7 \text{ x } 13}{0.38 \; x \; 2{,}000}$$

Ep_A = 510 tons of VOC per year.

Table 4.6.14-1
Commercial and Residential Gas-Can Population

County	Number Of Residential Gas-Cans	Number Of Commercial Gas-Cans	Number Of Commercial Lawn and Garden Gas-Cans	Number Of Commercial Non-Lawn and Garden Gas-Cans
Fairfield	268,881	21,351	270	21,081
Hartford	279,609	18,564	83	18,481
Litchfield	61,140	6,133	33	6,100
Middlesex	53,257	4,223	22	4,201
New Haven	268,724	17,427	61	17,366
New	86,962	6,017	22	5,995
Tolland	42,458	3,240	11	3,229
Windham	35,108	2,495	6	2,489
State Total:	**1,096,139**	**79,450**	**508**	**78,942**

Table 4.6.14-2
Summary of Daily Uncontrolled VOC Emissions From Residential Gas-Cans

County	Permeation Emissions From Plastic Gas-Cans (lbs/day)	Permeation Emissions From Metal Gas-Cans (lbs/day)	Diurnal Emissions From Closed Plastic Gas-Cans (lbs/day)	Diurnal Emissions From Closed Metal Gas-Cans (lbs/day)	Diurnal Emissions From Open Gas-Cans (lbs/day)	Transport-Spillage Emissions From Closed Gas-Cans (lbs/day)	Transport-Spillage Emissions From Open Gas-Cans (lbs/day)
Fairfield	396	4	348	27	3,076	110	80
Hartford	412	4	362	28	3,199	114	83
Litchfield	90	1	79	6	699	25	18
Middlesex	78	1	69	5	609	22	16
New Haven	396	4	348	27	3,074	110	80
New	128	1	113	9	995	35	26
Tolland	63	1	55	4	486	17	13
Windham	52	0	45	4	402	14	10
State Total:	**1,615**	**16**	**1,419**	**110**	**12,540**	**447**	**326**

Table 4.6.14-3
Summary of Daily Uncontrolled VOC Emissions From Commercial Gas-Cans

County	Permeation Emissions From Plastic Gas-Cans (lbs/day)	Permeation Emissions From Metal Gas-Cans (lbs/day)	Diurnal Emissions From Closed Plastic Gas-Cans (lbs/day)	Diurnal Emissions From Closed Metal Gas-Cans (lbs/day)	Diurnal Emissions From Open Gas-Cans (lbs/day)	Transport-Spillage Emissions From Closed Lawn Gas-Cans (lbs/day)	Transport-Spillage Emissions From Open Lawn Gas-Cans (lbs/day)	Transport-Spillage Emissions From Closed Non-Lawn Gas-Cans (lbs/day)	Transport-Spillage Emissions From Open Non-Lawn Gas-Cans (lbs/day)
Fairfield	29	1	25	4	352	5	6	46	62
Hartford	25	1	22	4	306	1	2	40	55
Litchfield	8	0	7	1	101	1	1	13	18
Middlesex	6	0	5	1	70	0	1	9	12
New Haven	23	0	21	4	287	1	1	38	51
New	8	0	7	1	99	0	1	13	18
Tolland	4	0	4	1	53	0	0	7	10
Windham	3	0	3	1	41	0	0	5	7
State Total:	**106**	**2**	**94**	**17**	**1,309**	**8**	**12**	**171**	**233**

Table 4.6.14-4
Summary of Daily and Annual Controlled VOC Emissions From Residential and Commercial Gas-Cans

County	Total Daily Gas-Can Emissions (lbs/day)	Total Annual Gas-Can Emissions (tons/year)
Fairfield	4,259	510
Hartford	4,340	520
Litchfield	995	119
Middlesex	842	101
New Haven	4,160	498
New London	1,355	162
Tolland	669	80
Windham	547	65
State Total:	**17,167**	**2,055**