Consumer Products VOC Equivalency

This technical memorandum summarizes the methodology and rationale used to construct and apply an alternative focus to Volatile Organic Compounds (VOC) emissions for the Consumer Products Program, namely VOC Equivalency. The metric of VOC Equivalence was used in the Consumer Products Program 2022 State Implementation Plan (SIP) commitment. More recently, VOC Equivalence was used in the selection of categories in the 2023 Survey to subsequently evaluate for regulatory action aimed at meeting the 2022 SIP commitment.

Overview of Consumer Products Regulatory History

Ozone, the main ingredient of smog, continues to threaten the health of many Californians. Although the state's air is the cleanest it has been in over 30 years, most Californians still live in areas where smog reaches unhealthy levels. Reducing air pollution from cars and businesses has not been enough to meet state and federal air quality standards. Smaller sources of ozone-forming emissions, including consumer products which collectively form one of the largest contributors of emissions, also need to pollute less. To achieve these standards, the California Air Resources Board (CARB) mandates limitations and/or restrictions on certain types of chemicals in consumer products that have harmful health effects and cause pollution and are considered Total Organic Gases (TOG).

TOG refers to organic gas compounds emitted to the atmosphere, excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, and ammonium carbonate. TOG compounds fall under one of the following three classifications defined in Article 2 of the Consumer Product Regulations:

- **Volatile Organic Compounds (VOCs)**. VOCs are the most volatile organic compounds and are defined under Title 17 California Code of Regulations (CCR), section 94508(a)(138).
- **Low vapor pressure volatile organic compounds (LVP-VOCs)**. LVP-VOCs are less volatile than VOCs and are defined under Title 17, California Code of Regulations, in section 94509(a)(83).
- **Exempt Volatile Organic Compounds (Exempt-VOCs).** Exempt-VOCs have low reactivity and minimal contribution to ozone formation and therefore are exempted from the definition of VOC under Title 17 CCR, section 94508(a)(138). A list of chemicals exempted from the definition of VOC in consumer products can be found in Article 2 of the Consumer Product Regulations, § 94508. Definitions 138.

The Consumer Products Regulatory Focus on VOC

The Consumer Products Program encompasses the following seven distinct sectors:

I   All Adhesives, Sealants, and Related Products

II   All Household and Institutional Products

III   Personal Care Products

IV   Pesticide Products

V   Solvents and Thinning-Related Products

VI   Vehicle and Marine Vessel Aftermarket Products, and

VII   Aerosol Coating Products

For much of the history of the program, the regulatory framework for all Consumer Products has been based on their VOC content. VOCs are an important precursor, or component in the formation of ground level ozone, a major part of California's smog problem. By regulating the amount of VOCs in consumer products, CARB's Consumer Products program has been helping to reduce public exposure to the hazards associated with ground level ozone. VOCs used in consumer products are counted towards the total product VOC content for compliance purposes. In the Federal Clean Air Act (CAA) and in California Code of Regulations, this early focus on VOCs was designed to prioritize reductions in VOC compounds that most readily participate in ozone formation.

Aerosol Coatings are an exception to the regulatory focus on VOCs. For the Aerosol Coatings sector the regulatory focus was expanded beyond VOCs, and a distinct regulatory approach based on the reactivity of all organic gas compounds has been implemented under Article 3 Aerosol Coating Product Regulation | California Air Resources Board.

Therefore, the term Consumer Products in the subsequent part of this document refers to the other six sectors listed above.

Chemically formulated consumer products such as personal care products, household care products, and automotive care products are a significant source of VOC emissions and have been regulated as a source in numerous rulemakings since 1989. Consumer products are the largest source category of VOC and LVP-VOC emissions in the South Coast and statewide. For more than thirty years, CARB has taken actions pertaining to the regulation of consumer products. CARB regulations have set VOC limits for over 130 consumer product categories. These regulations have reduced VOC emissions by about 50 percent between 1990 and 2020 relative to uncontrolled levels. Despite these existing regulations, consumer product emissions increased as California's population and associated consumer product usage grew. Without continued attention, consumer product emissions are projected to be the largest statewide source of VOC and LVP-VOC emissions.

TOG classifications and the Ozone Apportionment of the Consumer Products Program

The most recent three-year survey conducted by CARB for the years 2013 to 2015 included 451 categories of Consumer Products as shown at 2015_CP_Survey_Summary_data_2019-12-09 (Autosaved).xlsx The majority of these 451 Consumer Products categories have not been regulated to date, while a number of categories have been regulated repeatedly. The current emissions inventory and speciation profiles used for Ozone SIP Planning and attainment modeling are based on the data shown in the 2015_CP_Survey_Summary_data_2019-12-09 (Autosaved).xlsx. Looking at all 451 consumer product categories, the emissions, ozone reactivity and ozone forming potential contribution of each of the three TOG classifications, namely, VOC, LVP-VOC and Exempt-VOC, are shown in the following figure.
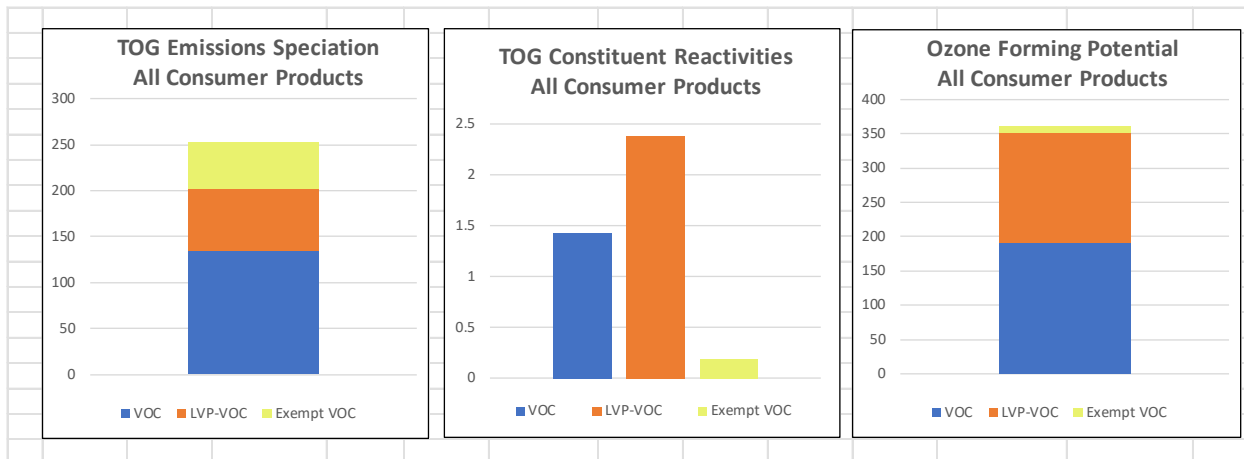
Figure 1. Consumer Products Program TOG Emissions, Reactivity and Ozone Forming Potential

The TOG classification apportionment on the left in Figure 1 shows that the emissions (in units if tons per day) of LVP-VOCs are nearly half those of the more volatile VOCs. The weighted reactivity (in units of mass ozone per mass of TOG classification) of the less volatile LVP-VOCs shown in the middle is nearly 71% higher than the weighted reactivity of the more volatile VOCs. The ozone forming potential (OFP) of each TOG classification shown (in units if tons per day) on the right is equal to its emissions multiplied by its respective reactivity. On the right, the ozone forming potential of the less volatile LVP-VOCs contributes to 44% of the total OFP of all Consumer Products and is comparable to the predominant OFP 53% contribution of the more volatile VOCs. Exempt VOC emissions on the left are 20% of the TOG emissions, but due to their minimal reactivity they are seen on the left to have a minimal 3% contribution to OFP.

2022 State SIP Strategy Consumer Products Commitment

A fundamental aspect of the regulatory history of the program is that LVP-VOCs used in consumer products are not counted towards the total product VOC content for compliance purposes. Although this exemption of LVP-VOCs was designed to prioritize reductions in the more volatile VOC compounds that most readily participate in ozone formation, as shown in the preceding figure the less volatile LVP-VOCs are also contributing significantly towards ozone formation. The volatility and reactivity towards ozone formation of organic compounds are two independent parameters. Scientific research has established that individual LVP-VOCs can be more reactive than VOCs as shown in the weighted average reactivity of LVP-VOCs in Figure 1 that reflects the current Consumer Products emissions inventory.

The main conclusion from the representation of the current status of the Consumer Products Program shown in Figure 1 is the need to expand the regulatory focus beyond VOCs to capture the contribution of all three TOG classifications towards ozone formation. In particular, the significant contribution of LVP-VOCs towards ozone formation needs to be addressed through a new expanded focus on OFP reduction from all TOG classifications. The CAA and CARB's SIP commitments for reductions towards ozone attainment have been traditionally defined as VOC emission reductions.

However, Figure 1 demonstrates the need to reduce OFP holistically regardless of the TOG classification of the ozone precursors, instead of the conventional focus on VOC emission reductions.

Therefore, for the first time in the Program's history CARB's 2022_State_SIP_Strategy.pdf adopted an alternative to the conventional VOC reductions in the form of a SIP commitment expressed as equivalent VOC reductions. The VOC equivalency concept discussed below in this document was previously presented to stakeholders in 2023.

Table 1 below is a representation of the array of 451 Consumer Product categories captured in the current emissions inventory and speciation profiles from the most recent three-year survey conducted by CARB shown at: 2015_CP_Survey_Summary_data_2019-12-09 (Autosaved).xlsx

Table 1. Consumer Product Categories and their Category Metrics

Product Category	Mass	VOC Emissions (mass VOC/per time)	$PWMIR_{AVG}$ (mass ozone/mass of category)	OFP
PC_1	M_1	VOC_1	$PWMIR_1$	OFP_1
PC_2	M_2	VOC_2	$PWMIR_2$	OFP_2
PC_3	M_3	VOC_3	$PWMIR_3$	OFP_3
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PC_N	M_N	VOC_N	$PWMIR_N$	OFP_N
N Total number of all product categories	M_{TOT} Total mass of all product categories	VOC_{TOT} Total VOC emissions of all product categories	$PWMIR_{AVG}$ Average product reactivity of all categories	OFP_{TOT} Total ozone of all product categories

Each category **i** of the 451 Consumer Product categories shown in Table 1 is defined by:

M_i the mass category of products sold

VOC_i the VOC emissions of the category products

$PWMIR_I$ the sales-weighted average reactivity of the category products

OFP_i the ozone forming potential of the category products

The category parameters VOC_i, $PWMIR_I$ and OFP_i incorporate any applicable fate and transport adjustments. The sales-weighted average reactivity of a category $PWMIR_i$ is defined as:

EQUATION (1) $PWMIR_i = \Sigma (M_P * PWMIR_P) / \Sigma (M_P) = \Sigma (M_P * PWMIR_P) / M_i$

where M_P is the sales mass of a product P and $PWMIR_P$ is the Product Weighted Maximum Incremental Reactivity of a product P. The total mass category of products sold M_i is the sum of the mass sold of each product M_P in the category.

The ozone forming potential OFP_i of each category **i** is the multiplication of its mass M_i and its sales weighted average reactivity $PWMIR_i$ as shown below:

EQUATION (2) $OFP_i = M_i * PWMIR_i$

A programmatic shift from a VOC focus to a holistic OFP focus requires a consistent and methodical conversion of each category's OFP_i to an appropriate alternative metric that conveys the relationship

between the VOC emissions and OFP of the entire set of 451 categories currently included in the Consumer Products emissions inventory.

The obvious and legitimate conversion factor **R** for a programmatic shift from VOC to OFP is the ratio of the total VOC emissions VOC_{TOT} and the total OFP_{TOT} of the entire set of 451 categories as shown below:

EQUATION (3) $R = VOC_{TOT}/OFP_{TOT}$

where the total VOC emissions VOC_{TOT} of the entire set of 451 categories shown in Table 1 is the sum of the VOC emissions VOC_i of all categories as shown below:

EQUATION (4) $VOC_{TOT} = \Sigma(VOC_i)$

and where the total ozone forming potential OFP_{TOT} of the entire set of 451 categories shown in Table 1 is the sum of the ozone forming potential OFP_i of all categories as shown below:

EQUATION (5) $OFP_{TOT} = \Sigma(OFP_i)$

When the ozone forming potential OFP_i of each category shown in Table 1 is multiplied by the programmatic conversion factor R, the result is an expression of each category's VOC Equivalency $VOC_{EQ\,i}$ as shown below:

EQUATION (6) $VOC_{EQ\,i} = R * OFP_i$

The above equation shows that the new metric of VOC equivalent emissions $VOC_{EQ\,i}$ for each category **i** is proportional to the category's ozone forming potential OFP_i.

The sum of the VOC equivalent emissions $VOC_{EQ\,I}$ of all 451 categories $\Sigma(VOC_{EQ\,i})$ is shown below:

EQUATION (7) $\Sigma(VOC_{EQ\,i}) = \Sigma(R * OFP_i) = R*\Sigma(OFP_i)$

Combining Equation (5) and Equation (7) results in:

EQUATION (8) $\Sigma(VOC_{EQ\,i}) = R * OFP_{TOT}$

And then combining Equation (3) and Equation (8) results in:

EQUATION (9) $\Sigma(VOC_{EQ\,i}) = VOC_{TOT}$

Equation (9) shows that the sum of the VOC equivalent emissions of all 451 categories in the program $VOC_{EQ\,TOT}$ is equal to the sum of the total VOC emissions of all 451 categories in the program VOC_{TOT}

It is important to recognize that the mathematical result in Equation (9) reflects the systematic and methodical calculation of each category's VOC Equivalency $VOC_{EQ\,i}$ through a consistent and programmatic conversion of each category's ozone forming potential OFP_i

Equation (9) conveys that the introduction of the category metric of VOC Equivalency $VOC_{EQ\,I}$ through a systematic and methodical conversion of the category ozone forming potential OFP_i

VOC Equivalency serves as a means for reranking the programmatic importance around a category's ozone forming potential rather than its VOC emissions. The reranking of the importance of the 451 categories of consumer products based on each category's VOC Equivalency $VOC_{EQ\,i}$ allows a programmatic focus shift away from VOC to OFP.

Table 2 shows the top ranked VOC categories in the current Consumer Products emissions inventory projected in the SIP attainment year 2037. Table 3 shows the top ranked OFP categories in the current Consumer Products emissions inventory projected in the SIP attainment year 2037.

Table 2. Top 20 VOC Emissions Categories in the SIP Attainment Year 2037

Category Code	Category Name	2037 VOC (tpd)
30201	Anti-microbial Dry Hand Wash (Hand Sanitizer)	17.14
30502	Personal Fragrance Product with 20% or less fragrance	15.95
30606	Hair Finishing Spray	14.93
30710	Rubbing Alcohol	13.30
20305	Disinfectant (aerosol)	7.04
20311	General Purpose Cleaner (non-aerosol)	6.01
30411	Sunscreen (hair or body) (aerosol)	5.05
10115	Plastic Pipe Cement and Prime-	3.85
20903	Laundry Detergent	2.99
20103	Dual Purpose Air Freshener/Disinfectant (aerosol)	2.99
30501	Deodorant Body Spray	2.54
30101	Antiperspirant	2.23
20102	Air Freshener, Single Phase Aerosol	2.22
20701	Charcoal Lighter Material	2.21
21013	Multi-purpose Lubricant (including solid and semisolid products)	2.17
20101	Air Freshener, Double Phase Aerosol	2.02
31006	Mouthwash/Rinse	1.94
40403	Crawling Bug Insecticide (aerosol)	1.93
60205	Denatured Alcohol	1.90
20601	Aerosol Cooking Spray	1.82

As shown in Table 3, the ranking of categories in terms of VOC equivalent emissions is identical to the OFP ranking because each category's VOC equivalency **VOC$_{EQ\,i}$** is proportional to its ozone forming potential **OFP$_i$** as shown in Equation (6).

The ozone forming potential **OFP$_i$** of each category **i** is the multiplication of its mass **M$_i$** and its sales weighted average reactivity **PWMIR$_i$** as shown in Equation (2). It is important to recognize that a category with a high sales weighted average reactivity **PWMIR$_i$** may have a relatively low ozone forming potential **OFP$_i$** if its category mass of products sold **M$_i$** is low. And inversely, a category with low sales weighted average reactivity **PWMIR$_i$** may have a relatively high ozone forming potential **OFP$_i$** if its category mass of products sold **M$_i$** is high.

Table 3. Top 20 OFP and VOC Equivalent Emissions Categories in the Year 2037

Category Code	Category Name	2037 OFP (tpd)	2037 VOC Equivalent (tpd)
20311	General Purpose Cleaner (non-aerosol)	28.84	10.17
30502	Personal Fragrance Product with 20% or less fragrance	27.57	9.72
30201	Anti-microbial Dry Hand Wash (Hand Sanitizer)	26.21	9.24
20903	Laundry Detergent	26.00	9.17
30404	Hand and Body Conditioner, Cream, Lotion, and Moisturizer	22.96	8.10
30606	Hair Finishing Spray	21.72	7.66
20104	Air Freshener, liquid/pump spray	14.64	5.16
30102	Deodorant	12.26	4.32
10115	Plastic Pipe Cement and Primer	11.60	4.09
20305	Disinfectant (aerosol)	10.87	3.83
30603	Dye, permanent	9.85	3.47
30602	Conditioner without styling claims	9.54	3.36
20153	Scented Candle	9.28	3.27
21405	Floor Wax Stripper	9.18	3.24
30710	Rubbing Alcohol	8.37	2.95
20326	Oven or Grill Cleaner (non-aerosol)	7.97	2.81
30411	Sunscreen (hair or body) (aerosol)	7.77	2.74
30207	Body Wash/Mousse/Gel/Soap/Foam/Scrub	7.69	2.71
20919	Liquid Fabric Softener	6.72	2.37
20313	General Purpose Degreaser (non-aerosol)	6.03	2.13

Regardless of whether the ozone forming potential **OFP$_i$** of a category **i** is relatively high or low compared to other categories, it is important to recognize that each category's calculated VOC Equivalency **VOC$_{EQ\,i}$** is a consistent and methodical reflection of its sales weighted average reactivity **PWMIR$_i$**. The methodology used to calculate each category's VOC equivalency **VOC$_{EQ\,i}$** by multiplying each category's ozone forming potential **OFP$_i$** with the programmatic conversion factor **R** reflects each category's sales weighted average reactivity **PWMIR$_i$** without distortion or bias. The programmatic conversion factor **R** is the ratio of the total VOC emissions **VOC$_{TOT}$** and the total **OFP$_{TOT}$** of the entire set of 451 categories in the current consumer products emissions inventory.

Selection of 2023 Survey Categories on the basis of VOC equivalency

The planning exercise conducted for the 2023 Survey selection of consumer product categories to meet the 2022 SIP commitment of 20 tons per day (tpd) of VOC equivalent reductions consisted of:

I   Categories most recently regulated in 2021 were eliminated from consideration for new regulatory consideration.

II Then the remaining categories were ranked according to their ozone forming potential **OFP$_i$**

III Then a planning exercise was pursued that assumed a programmatic percent reduction **X%** in the average reactivity **PWMIR$_i$** of all remaining product categories

IV Then followed the calculation of individual category reductions in ozone forming potential $\Delta(OFP_i)$,

V   And then followed by a calculation of the corresponding VOC equivalent reductions $\Delta(VOC_{EQ\,i})$. , across each category

VI Identified the number of categories needed to meet the 2022 SIP commitment of 20 tpd of VOC equivalent reductions by adding up the individual ranked categories VOC equivalent reductions from Step IV above

VII The planning exercise was then repeated for successive series of programmatic percent reductions **X%** in the average reactivity **PWMIR$_i$** of all remaining product categories followed by the subsequent steps V and VI above.