2. Scope and Comparison of Alternatives

2.1 Identification of Alternatives

An array of resource documents are available (see Appendix 1) that review in detail the broad range of paint removal options available.[8] These documents reveal three generally recognized categories of paint stripping methods:

- Physical/mechanical stripping, which involves the use of abrasion methods. Examples include: use of metal tools for scraping, sand paper, and media blasting (e.g., plastic media blasting, wheat media blasting, liquid nitrogen blasting, etc.).
- Pyrolytic/thermal stripping, which involves the use of heat. Examples include: heat guns, steam, and laser stripping.
- Chemical stripping, which uses solvents or alkaline or acidic chemicals to strip paint.

The performance and safety of the paint stripping methods described above will vary depending on the environmental conditions in which they are applied. For example, not all methods are appropriate for use indoors in residential settings.

This BizNGO analysis models the perspective of a chemical formulation manufacturer of methylene chloride-based paint stripper consumer products. While the three categories of paint stripping methods above offer a range of alternatives to consider, not all methods are compatible with the category of consumer or professional product paint strippers as justified in Section 1.1. Nor are all the alternatives relevant to a chemical stripping product manufacturer seeking to identify and adopt a safer alternative consumer product that can achieve the same product functional requirements as reviewed in Section 1.1 and preferably, the same functional use as reviewed in Section 1.2, as methylene chloride in the current product.

For Stage 1 analysis BizNGO prioritized alternative chemical stripping agents. Primary alternatives to be further screened and analyzed include those with a solvent function to replace the function of methylene chloride in the existing paint stripping product (see Section 1.2). In order to expand the options of potential chemical alternatives, chemical formulations that can strip paint via other functions will also be considered. In this chemical screening assessment, acidic and alkaline strippers will also be considered.

Alternatives not prioritized and considered in this Stage 1 assessment include: (1) non-chemical alternatives, as the expected economic costs for a chemical formulator associated with such a transition are expected to be infeasible and (2) alternatives not intended for consumer or professional uses, including: media blasting and alkaline and acid chemical stripping that require use in immersion tanks.

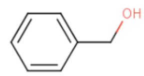
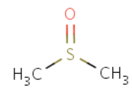
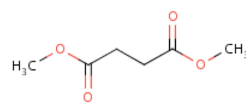
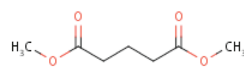
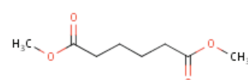
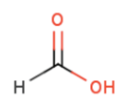
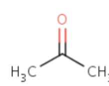
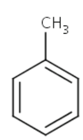
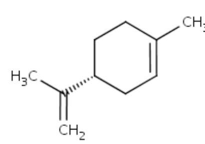
While there are a number of alternative paint strippers available in consumer retail outlets, including pyrolytic techniques and physical/mechanical techniques, these alternatives are not economically feasible options for a chemical formulator whose existing plant infrastructure is designed for chemical product manufacturing. While economic feasibility is considered in Stage 2 of the assessment, for the purpose of this model assessment, the costs required of a chemical formulator to change its business model to the manufacturing of metal products (e.g., metal scrappers), or to paper product manufacturing (e.g., sand paper), or article manufacturing (e.g., heat guns) would rank lowest among the alternatives due to financial infeasibility. Required investments were assumed to include new plant infrastructure (capital expenditures associated with building new plants, purchasing new manufacturing equipment, etc.) as well as personnel costs (e.g., unemployment/severances for downsized chemical staff).

Additional alternative paint stripping methods not considered are primarily for industrial uses as the nature of the stripping process requires use in industrial facilities. For example, media blasting involves propelling specific media types (e.g., polymers, wheat, or carbon dioxide) at high speeds at the substrate being stripped. While these methods have been shown to be quite effective,[9] media blasting technology is not readily available for purchase in consumer retail outlets. While in theory media blasting could be performed in residential settings (e.g., among automotive hobbyists to strip paint from cars), industrial equipment is required. Several alkaline and acid stripper products require use in immersion tanks that are often heated to high temperatures. Again, these products are designed for industrial uses, not consumer or professional uses in residential or institutional settings.

Eleven chemical alternatives were prioritized for the hazard assessment step (Table 1). These alternatives

TABLE 1

Chemical Properties of Methylene Chloride and Potential Alternatives

Chemical (or mixture)	CASRN	Water Solubility	Molecular Formula	Molecular Structure	Vapor Pressure
Methylene chloride	75-09-2	1.3X10^4 mg/L @ 25°C	CH_2Cl_2		435 mmHg @ 25°C
Benzyl alcohol	100-51-6	42,900 mg/L @ 25°C	C_7H_8O		0.94 mmHg @ 25°C
2-(2-butoxyethoxy) ethanol	112-34-5	1X10^6 mg/L @ 25°C	$C_8H_{28}O_2$		0.0219 mmHg @ 25°C
Caustic soda	1310-73-2	Soluble in water—1g/0.9ml (no temperature noted)	HNaO	Na — OH	1.82X10^{-21} mmHg @ 25°C (extrapolated)
Dimethyl sulfoxide (DMSO)	67-68-5	1X10^6 mg/L @ 25°C	C_2H_6OS		0.61 mmHg @ 25°C
1,3-dioxolane	646-06-0	1X10^6 mg/L @ 25°C	$C_3H_6O_2$		79 mmHg @ 20°C
Estasol (mixture of 3 dibasic esters) **(a) Dimethyl succinate (15–25%)** **(b) Dimethyl glutarate (55–65%)** **(c) Dimethyl adipate (10–25%)**	95481-62-2	5.3x10^{4}g/L @20°C	(a) $C_6H_{10}O_4$ (b) $C_7H_{12}O_4$ (c) $C_8H_4O_4$	(a)  (b)  (c) 	(a) 0.41 mmHg @ 20°C*
Formic acid	64-18-6	1X10^6 mg/L @ 25°C	CH_2O_2		42.6 mmHg @ 25°C
Hydrocarbon solvents (likely used as a mixture, but assessed individually) **(a) methanol** **(b) acetone &** **(c) toluene**	(a) 67-56-1 (b) 67-64-1 (c) 108-88-3	(a) 1X10^6 mg/L @ 25°C (b) 1X10^6 mg/L @ 25°C (c) 526 mg/L@ 25°C	(a) CH_4O (b) C_3H_6O (c) C_7H_8	(a) H_3C — OH (b)  (c) 	(a) 127 mmHg @ 25°C (b) 232 mmHg @ 25°C (c) 28.4 mmHg @ 25°C
d-Limonene	138-36-3	13.8. mg/L @ 25°C	$C_{10}H_{16}$		1.98 mm Hg @ 25°C

Sources: ChemIDplus: *http://chem.sis.nlm.nih.gov/chemidplus* & Hazardous Substance Databank *http://toxnet.nlm.nih.gov/newtoxnet/hsdb.htm*.
* EPA 2008: *http://www.epa.gov/hpvis/rbp/Dibasic%20esters.Web.SupportDocs.031808.pdf*.

were identified through a review of publicly available reports from industry, government, and/or government research sponsored institutions.[10] This list of eleven candidate alternatives represents those alternatives with the greatest potential of being viable. These eleven alternatives were prioritized based on: (a) a review of existing material safety data sheets (MSDSs) demonstrating that these alternatives are being used in paint strippers on the market today;[11] (b) case study experience (including those listed on product specifications);[12] and (c) those also considered a priority by the California Department of Toxic Substances Control (DTSC) as they are referenced in its *Priority Product Profile: Paint Strippers Containing Methylene Chloride* report.[13] See Appendix 1 for further information specific to the demonstration project context of this assessment. One research article was also particularly useful as it uses the Hansen's solubility parameter, vapor pressure, and flashpoint among other physicochemical properties to identify "the sweet spot" of solvents with similar properties to methylene chloride to guide the selection of alternatives that function similarly.[14] While there is growing interest in bio-based solvents, including methyl soyate and lactate esters, additional research and development are needed and these options were excluded at this point in time in the Stage 1 assessment.

While a desirable aim is for the chosen alternative to achieve the same functional use as methylene chloride in paint stripping products, the candidate alternatives should not be considered drop-in substitutes. Product formulations will likely change, requiring new chemicals to be added to achieve the necessary performance. Thus an assessment of technical feasibility during Stage 2 of this analysis is essential. As necessary during Stage 2, additional assessments will be performed on formulation chemicals identified as necessary for the product function and performance in order to minimize the risk of regrettable substitutions.

Some physicochemical characteristics of the chemical of concern—methylene chloride—and the eleven candidate alternatives are listed in Table 1. The dibasic esters included in this hazard screening assessment are a mixture of 3 dibasic esters, known as estasol. The U.S. Environmental Protection Agency (EPA) has concluded that the three dibasic esters included in the mixture produce similar levels of toxicological effects, such that information on one type of dibasic ester in the mixture is expected to represent the toxicity of the category as a whole.[15] While resource documents suggest that a mixture of hydrocarbon solvents, including acetone, methanol, and toluene, may be suitable alternatives to methylene chloride, these chemicals are screened separately because their hazards are not expected to be similar (in contrast to dibasic esters).

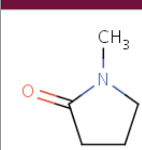
Table 2 lists an alternative that was excluded from further screening and analysis: 1-Methyl-2-pyrrolidone (NMP). While this alternative was identified as a candidate using the sources identified in Appendix 1, and is often found as a co-solvent with alternatives identified in Table 1 in products available on the market today, DTSC states in its *Priority Product Profile: Paint Strippers Containing Methylene Chloride*,[16] that NMP alternatives for methylene chloride are not to be considered because "DTSC does not recognize NMP as a 'safer alternative' to methylene chloride." NMP is considered a reproductive and developmental toxicant under California's Proposition 65 and is included on DTSC's list of candidate chemicals. For these reasons, NMP was screened out of the assessment.

2.1 Identification of Relevant Comparison Factors

According to the California Safer Consumer Products (SCP) regulations, comparison factors are relevant if they:

- "Make a material contribution to one or more adverse public health impacts, adverse environmental impacts, adverse waste and end-of-life effects, and/or materials and resource consumption impacts associated with the priority product and/or one or more alternatives under consideration; and
- There is a material difference in the factor's contribution to such impact(s) between the priority product and one or more alternatives under consideration and/or between two or more alternatives."

TABLE 2
Alternative Screened-out of the Assessment

Chemical (or chemical mixture)	CASRN	Description (including flammability)	Molecular Formula	Molecular Structure	Vapor Pressure
1-methyl-2-pyrrolidone (NMP)	872-50-4	A clear colorless liquid with a "fishlike" odor. Water soluble (water solubility = $1X10^6$ mg/L @ 25°C)	C_5H_9NO		0.345 mmHg @ 25°C

Factors to be considered for relevance and compliance with the SCP regulations, along with their associated exposure pathways and life cycle segments, include the following:

- adverse environmental impacts;
- adverse public health impacts;
- adverse waste and end-of-life impacts;
- environmental fate;
- materials and resource consumption impacts;
- physical chemical hazards; and
- physiochemical properties.

None of these factors required quantitative analysis to determine relevance; qualitative evaluation was sufficient as reviewed below.

2.1.1 Adverse Environmental Impact

Adverse environmental impact is a relevant impact factor. Given that some consumer use applications of paint strippers will likely result in residual paint stripper being subsequently flushed down the drain—for example, use in bathtub refinishing—impact on water quality, including interference with the microbial activity of waste water treatment processes as well as aquatic toxicity, should be considered. Aquatic toxicity (acute and chronic) will be addressed in Section 3 using the GreenScreen® version 1.2. Water, waste water/ sewage treatment microorganisms will be addressed in the life cycle assessment in Stage 2 of the analysis as a preliminary review of the hazard literature for the eleven alternatives reveals a lack of study data. Because methylene chloride is very volatile and quickly evaporates to air, adverse air quality impacts associated with the alternatives should also be considered. Specific air quality impacts such as ozone depletion and greenhouse gases will be assessed in the life cycle considerations in Stage 2 of this analysis.

2.1.2 Adverse Public Health Impact

Adverse public health impact is a relevant comparison factor, as community and occupational health are of concern. Adverse public health impact factors to be compared in Section 3 include five hazard endpoints as evaluated using the GreenScreen® version 1.2 hazard assessment tool. These hazard endpoints are "critical" endpoints, or those categorized by GreenScreen® as Group I hazard endpoints: carcinogenicity, genotoxicity/mutagenicity, reproductive toxicity, developmental toxicity, and endocrine activity. Health endpoints of additional concern are categorized as Group II endpoints and include: acute toxicity, systemic toxicity and organ effects, neurotoxicity, skin sensitization, respiratory sensitization, skin irritation, and eye irritation.[17] The hazard assessment method in GreenScreen® version 1.2 is based on the Globally Harmonized System for Classification and Labeling (GHS) and uses national and international precedents from authoritative agencies regarding evidence classifications for specific hazard endpoints wherever feasible. The hazard assessment method was developed in conjunction with a technical advisory committee comprised of experts from non-governmental organizations (NGOs), government, academia, and industry.

2.1.3 Adverse Waste and End-of-Life Impacts

Adverse waste and end-of-life impacts—such as flushing residual stripper down the drain—are relevant comparison factors. These factors will be addressed in the life cycle analysis section in Stage 2 of the analysis.

2.1.4 Environmental Fate

Environmental fate is a relevant comparison factor. Both bioaccumulation and persistence will be addressed in Section 3 of this report. Additional environmental fate factors related to atmospheric deposition, such as global warming, acid rain, and ozone depletion will be addressed in Stage 2 of the analysis.

2.1.5 Material and Resource Consumption Impact

Material and resource consumption impact are relevant comparison factors. These factors, in addition to chemical and product manufacturing, transportation, and associated resource consumption (primarily energy) will be examined using life cycle assessment tools in Stage 2 of the analysis.

2.1.7 Physical Chemical Hazards

Physical hazards such as flammability and reactivity are important comparison factors and could significantly influence the inherent hazard of a given alternative and the associated risk to populations exposed. In particular, methylene chloride is a non-flammable solvent and flammability may be an important safety consideration in some applications. These two physical chemical safety hazards will be addressed in Section 3 of this report using GreenScreen®.

2.1.8 Physicochemical Properties

Physicochemical properties are relevant factors if they contribute to specific public health or environmental impacts (including environmental fate). Considering that the chemical of concern and its potential alternatives are solvents, a key physicochemical property is vapor pressure and water solubility as outlined in Table 1. Other physicochemical properties that are indicators of environmental persistence and bioaccumulation will be addressed in Section 3 of this report using GreenScreen®.

2.2 Quantities of the Chemical of Concern or Alternative Replacement Chemicals

Methylene chloride in consumer paint stripping products typically comprises 20%-90% of the formulation weight.[18] The formulation weights of alternatives similarly reflect this broad range of 20%-95% by weight based on paint stripping product formulations on the market that contain the candidate alternatives.[19] It is quite likely that a replacement formulation will have several active ingredients whose combined action replaces the function of methylene chloride. Until a product is definitively reformulated and tested it is not possible to estimate the volume or mass of the chemical of concern or alternative replacement chemical(s) that is/are or would be placed into the stream of commerce in California.[20] To the extent possible, this issue will be further addressed in Stage 2 of the analysis within the assessment of technical feasibility.