Abridged Alternatives Analysis Report for Two-component Low- and High-pressure Spray Polyurethane Foam Systems Containing Unreacted Methylene Diphenyl Diisocyanate

Prepared for
American Chemistry Council
Center for the Polyurethanes Industry
Spray Foam Coalition
700 2nd Street NE
Washington, DC 20002

October 14, 2020

GRADIENT

www.gradientcorp.com
600 Stewart Street, Suite 1900
Seattle, WA 98101
206-267-2920

Table of Contents

Page

List of Tables

List of Figures

Abbreviations

2,4-MDI	Methylene Diphenyl Diisocyanate
4,4'-MDI	4,4'-Methylene Diphenyl Diisocyanate
AA	Alternatives Analysis
AAT	Alternatives Analysis Threshold
ACGIH	American Conference of Governmental Industrial Hygienists
ACH	Air Changes Per Hour
ACH_{50}	Air Changes Per Hour at 50 Pa Pressure Differential
ADP	Abiotic Depletion Potential
AP	Acidification Potential
ASTM	American Society for Testing and Materials
BCF	Bioconcentration Factor
BPA	Bisphenol A
CalDTSC	California Department of Toxic Substances Control
CalOEHHA	California Office of Environmental Health Hazard Assessment
CalOSHA	California Division of Occupational Safety and Health
CARB	California Air Resources Board
CAS No.	Chemical Abstracts Service Registry Number
CBC	California Building Code
CBES	California Building Efficiency Standard
CBI	Confidential Business Information
CCR	California Code of Regulations
CDPH	California Department of Public Health
CHDA	1,3- and 1,4-Cyclohexanedicarboxaldehyde
CO_2	Carbon Dioxide
cP	Centipoise
CPI	Center for the Polyurethanes Industry
CRC	California Residential Code
CSI	Chemical Scoring Index
DEG	Diethylene Glycol
DIY	Do It Yourself
DMEA	Dimethylethanolamine
ECHA	European Chemicals Agency
EP	Eutrophication Potential
EU	European Union
FHSA	Federal Hazardous Substances Act
FPLA	Fair Packaging and Labeling Act
GHS	Globally Harmonized System of Classification and Labelling of Chemicals
GRAS	Generally Recognized as Safe
GWP	Global Warming Potential
HAP	Hazardous Air Pollutant
HCS	Hazard Communication Standard
HDI	Hexamethylene-1,6-diisocyanate
HFC	Hydrofluorocarbon

HFO	Hydrofluoroolefin
Hg	Mercury
HSDB	Hazardous Substances Data Bank
HVLP	High Volume Low Pressure
IAPMO	International Association of Plumbing and Mechanical Officials
IBC	International Building Code
ICC	International Code Council
ICC-ES	ICC Evaluation Service
IECC	International Energy Conservation Code
IMAP	Inventory Multi-tiered Assessment and Prioritisation
IPCC	Intergovernmental Panel on Climate Change
IRC	International Residential Code
K_{ow}	Octanol-Water Partition Coefficient
K_{oc}	Organic Carbon Partition Coefficient
LCA	Life Cycle Assessment
MACT	Maximum Achievable Control Technology
MDI	Methylene Diphenyl Diisocyanate
MXDA	Meta Xylene Diamine
NAAQS	National Ambient Air Quality Standards
NAICS	North American Industry Classification System
NESHAP	National Emission Standards for Hazardous Air Pollutants
NFPA	National Fire Protection Association
NIOSH	National Institute for Occupational Safety and Health
ODP	Ozone Depletion Potential
OECD	Organisation for Economic Co-operation and Development
OSHA	Occupational Safety and Health Administration
PEL	Permissible Exposure Limit
pMDI	Polymeric Methylene Diphenyl Diisocyanate
PPE	Personal Protective Equipment
Pa	Pascal
PBT	Persistent, Bioaccumulative, and Toxic
PDS	Product Data Sheet
ppm	Parts Per Million
ppb	Parts Per Billion
psi	Pounds Per Square Inch
QSAR	Quantitative Structure-Activity Relationship
RBC	Residential Building Code
RCRA	Resource Conservation and Recovery Act
RE	Responsible Entity
REACH	Registration, Evaluation, Authorisation, and Restriction of Chemicals
REL	Recommended Exposure Limit
SCAQMD	South Coast Air Quality Management District
SCP	Safer Consumer Products
SDS	Safety Data Sheet
SFC	Spray Foam Coalition
SFP	Smog-Formation Potential
SFS	Spray Foam Systems
SMILES	Simplified Molecular-Input Line-Entry System

SOC	Standard Occupational Classification
SPF	Spray Polyurethane Foam
SPFA	Spray Polyurethane Foam Alliance
Syngas	Synthetic Gas
TAC	Toxic Air Contaminant
TBPD	Tetrabromophthalate Diol
TCPP	tris(2-Chloropropylphosphate)
TDI	Toluene Diisocyanate
TDS	Technical Data Sheet
TEDA	Triethylenediamine
TEP	Triethyl Phosphate
TLV	Threshold Limit Value
TMG	N,N,N',N'-Tetramethylguanidine
TSCA	Toxic Substances Control Act
TWA	Time-Weighted Average
UL	Underwriters Laboratories Inc.
US DOE	United States Department of Energy
US DOT	United States Department of Transportation
US EPA	United States Environmental Protection Agency
UVCB	Unknown or Variable Composition, Complex Reaction Product, and Biological Material
VOC	Volatile Organic Compound

Executive Summary

This Abridged Alternatives Analysis (AA) report was prepared on behalf of each of the responsible entities (REs) participating in the American Chemistry Council's Spray Foam Coalition (SFC). A current list of SFC members is provided in Section 1 of this report. The REs participating in the SFC represent a majority of the manufacturers (*i.e.*, systems houses) of two-component spray polyurethane foam (SPF) systems used for insulation and roofing and containing unreacted methylene diphenyl diisocyanate (MDI) (organized into four functional use groups, which are referred to herein as the Priority Products). It is worth noting that the REs do not use listed chemicals of concern (*i.e.*, 4,4'-methylene diphenyl diisocyanate [4,4'-MDI] [CAS No. 101-68-8] and generic MDI [CAS No. 26447-40-5]) as discrete chemicals. The MDI used in SPF formulations is polymeric MDI (pMDI, CAS No. 9016-87-9), which contains a mixture of MDI monomers and oligomers with different molecular weights.

This Abridged AA report was prepared largely based on publicly available information about the Priority Products and potential alternatives. Some additional and non-publicly available information on the potential alternatives was included if the patent holders are also REs involved in this Abridged AA. However, some of the patent holders chose to submit information separately as CBI.

This report sought to determine whether there are viable candidate alternative chemistries or alternative product designs or applications that might lower exposure to unreacted MDI from the Priority Products. We evaluated two types of possible alternatives – those based on patented non-MDI formulations and those involving SPF application approaches that might lower exposed to MDI/pMDI (which, because they contain MDI/pMDI, are still Priority Products). The available data for all of these possible alternatives are incomplete, and the available data cannot support the conduct of a full AA under the requirements of the California Safer Consumer Products (SCP) regulations. Nonetheless, in accordance with the SCP regulations' requirements for an Abridged AA report, we carried out an evaluation of these possible alternatives based on the limited existing data.

For the non-MDI-based alternative formulations, data on the final formulation and performance of these alternatives that would be needed to support a full AA under the SCP regulations are lacking. Based on what is currently known, none of the non-MDI-based alternative formulations are safer alternatives in terms of hazards, exposure potential, *and* performance. Additionally, based on the limited information available on internal costs, none of the identified alternatives seem economically feasible. None of the non-MDI-based alternative formulations have been commercialized, typically due to technical challenges in product performance. For the lower-exposure approaches, it is the REs' position that these products and patents do not meet the regulatory definition of a safer alternative in this Abridged AA. As demonstrated by Table 5.9, none of these alternatives presented a significant reduction of hazard or emissions. Further, due to the lack of an established Alternatives Analysis Threshold (AAT), it was not possible to adequately determine what level of reduction would qualify as a material difference as described by the "Alternatives Analysis Guide" (CalDTSC, 2017a). However, it is worth noting that this likely would not have had a material impact on the outcome of this AA report, as ingredient exposure is only a single metric within the SCP regulations. Additionally, it is unlikely that any of the lower-exposure approaches would be able to replace all four of the Priority Product groups. Replacing only one of the groups with a lower-exposure approach would result in a fragmented and unsustainable business model and would likely negatively impact worker training efforts. Thus, due to the lack of alternatives with sufficient data to support a full two-stage AA, conducting an Abridged AA is the appropriate analysis.

As required by the SCP regulations, the following is a summary of information contained in each section of the report.

- **Section 1** identifies the persons who oversaw preparation of this report.
- **Section 2** identifies the REs submitting this report and addresses how they will be submitting supply chain information as a separate confidential business information (CBI) submittal.
- **Section 3** identifies the Priority Products (low- and high-pressure two-component SPF products containing unreacted MDI) and the chemical of concern (MDI present as pMDI in the products). Tables listing the manufacturers and their respective Priority Products, correlated with the product names on SDSs and the Priority Product Notifications, are also included. Section 3 outlines a streamlined grouping approach for the Priority Products, because assessing all 170+ products would be overly complicated and lead to difficulties in understanding comparisons of the products. This section also identifies the function of the chemical of concern in the Priority Products (*i.e.*, rapid reaction with a polyol ingredient to produce a polyurethane foam that expands to serve as insulation, roofing material, and sealant). Section 3 also discusses the performance requirements of the Priority Products and identifies the tests that are conducted to evaluate their performance. Key performance criteria include thermal resistance, flame-spread index, smoke-developed index, core density, tensile strength, dimensional stability, and compressive strength. These performance criteria are mandated by building codes, and the Priority Products and any alternative(s) must be certified to meet the requirements specified in these codes. This section also summarizes other regulatory requirements to which the functional ingredients of the Priority Products and any alternatives would be subject, including California regulations related to volatile organic compounds (VOCs), greenhouse gas emissions, and Proposition 65. Section 3 concludes with a discussion of how a two-component SPF product formulated without unreacted MDI, pMDI, or an equivalently effective replacement would not be functional. Thus, simply removing the chemical of concern from the Priority Products' formulations without replacing it with a functionally equivalent ingredient is not an option.
- **Section 4** begins with a discussion of the REs' approach to performing the Abridged AA. Next is a scoping discussion that describes technologies that fall outside the scope of the Abridged AA. It is the REs' position that insulation products such as fiberglass, mineral wool, cellulose, natural fibers, polystyrene, cementitious foam, and polyisocyanurate are outside the scope of the evaluation, because they are not sprayable liquids, do not replicate all of the functions of SPF, involve a completely different product chemistry, and are outside the business model of REs that do not make such products. Section 4 next discusses how Internet and patent searches as well as RE interviews were carried out to identify possible alternatives. Through this process, several candidate alternative formulations were identified that use alternative chemistries *in lieu* of the chemical of concern. Limited data were identified for the non-MDI-based alternative formulations, because these formulations were obtained only from patents (*i.e.*, they are not commercialized), which discuss formulations in generic or exemplary form, making it difficult to judge the actual hazard, exposure potential, or performance of a product that might be marketed and sold. Through the alternatives search, several products or patents related to different ways to apply the current generic SPF formulation (*i.e.*, polyols and pMDI) that can reduce MDI exposure were also identified. These lower-exposure approaches involve minimizing exposure to unreacted MDI *via* equipment modifications.
- Section 4 concludes with a discussion of factors that were considered to be relevant to this AA. It includes a discussion of three conceptual exposure models that show how individuals and environmental receptors may be exposed to the chemical of concern in all the evaluated SPF products, *i.e.*, unreacted MDI/pMDI in the Priority Products and lower-exposure approaches as well as the corresponding reactive chemistries in the non-MDI-based alternative formulations. It

also describes what is known regarding the relevance of each life cycle aspect noted in the SCP regulations to the evaluation of the different alternatives. A life cycle assessment (LCA) is available for the Priority Products (based on a generic formula) but is not available for any of the alternatives, making quantitative comparisons among products to determine whether a material difference exists (CalDTSC's stated requirement) impossible. More qualitative arguments, based on raw materials used in producing the functional ingredients, their chemical properties and the required properties of any accepted alternative (*e.g.*, lifespan of product, packaging requirements) suggest that there are unlikely to be material differences between the Priority Products and the possible alternatives in terms of the following life cycle stages: raw material extraction, intermediate process materials, packaging, operations and maintenance, and reuse and recycling or end-of-life disposal. For some other life cycle stages (*i.e.*, waste generation and management and product manufacture), there are unlikely to be material differences between the Priority Products and the lower-exposure approaches, but information for the non-MDI-based formulations is insufficient to make a determination. Differences in the use/application phase, in terms of exposure potential for workers, may be materially different for the lower-exposure approaches, but data are lacking for the non-MDI-based alternative formulations, a number contain chemicals with different types of health hazards. Data are insufficient to make determinations for the resource consumption, transportation, and distribution phases of the life cycle. Overall, the available data are too limited to support a confident assessment of life cycle impacts.

- **Section 5** begins with a review of health hazard information for the Priority Products and the potential alternatives. We identified the functional ingredients of the generic Priority Product and the alternative formulations and approaches. From this, we concluded that all of the alternatives have essentially similar chemistries (*i.e.*, involving highly reactive chemicals). Notably, the alternatives all contain flame retardants, catalysts of some sort (*e.g.*, organotin or amine catalysts), as well as foam blowing agents and surfactants. Thus, any potential hazards from these additive ingredients would be expected to be similar across the identified alternatives. Because the listing is based on unreacted MDI/pMDI, only unreacted MDI/pMDI and the corresponding polyols that together form the polyurethane foam structure (which we term "functional ingredients") or the equivalent components (*i.e.*, components that react to form the polymer) of the non-MDI-based alternative formulations, were assessed in further detail. Next, we compared these functional ingredients using two primary data sources – European Chemicals Agency (ECHA) Registration, Evaluation, Authorisation, and Restriction of Chemicals (REACH) dossiers and Pharos – supplemented with additional sources when necessary. Using an adaptation of a published scoring approach, we found that the available ingredient-specific data suggest that the hazard scores for most of the identified alternatives are similar to those of the Priority Products, and hazard scores for a few of the alternatives were higher than those of the Priority Products. Only Firestone/Gaco Canary™ had a slightly lower ingredient-specific hazard compared to the equivalent generic Priority Product group (710 compared to 775 for generic Group 3 Priority Products), but also involves a possible trade-off between human health and environmental hazards. In many cases, a lack of toxicity data for particular ingredients was a significant determinant of the hazard score for an alternative. These data gaps would need to be filled in order to reach more definitive conclusions.

  It is also important to stress that while ingredient-specific hazards are presented in this section, ingredient-specific hazards may not reflect the hazards of an actual final product when it is fully reacted and installed. For example, MDI/pMDI is a dermal sensitizer; however, polyurethane (*i.e.*, the reacted and cured foam) is not a dermal sensitizer, even though it is made with MDI/pMDI. Furthermore, even product-level hazards do not automatically result in health risk without exposure. So, it is important to note when reviewing chemical hazard data on product ingredients that the indication of a high hazard does not necessarily equate to an actual health risk for the final installed product. Risk and hazard are different concepts.

Section 5 next discusses product performance. It was not possible to compare the performance parameters of the Priority Products and most of the potential alternatives because a complete set of necessary performance information was lacking for each alternative (and some had no available information at all). Two of the alternative approach products may meet the minimum performance requirements for SPF products. They are also Priority Products.

Section 5 continues with a review of the limited product-level emission data available for the functional ingredients of the Priority Products and the potential alternatives. However, because no emission data are available for the polyols, only data for MDI were reported. The limited available data suggest that some of the lower-exposure approaches (*i.e.*, Firestone/Gaco Profill System™ and BASF Patent No. 9592516 B2) have lower MDI emissions compared to the Priority Product. However, the study protocols used to evaluate these approaches were substantially different, making comparisons to the Priority Products difficult. Additionally, hazard and emissions are only a single metric and do not support the selection of a safer alternative on their own.

Section 5 next presents a review of relative exposure information for the Priority Products and the potential alternatives. We gathered chemical-specific physicochemical data for all of the alternatives' functional ingredients, as suggested in CalDTSC's "Alternatives Analysis Guide" (CalDTSC, 2017a). Although some data on chemical composition are available from the alternatives' patents, which allows some comparison of these alternatives' relative exposure potentials, there is substantial uncertainty, because other chemicals could be present in a final commercial formulation of these alternatives. Overall, the air, water, and soil exposure potentials of the alternatives' ingredients were not significantly lower than those of the Priority Products. For example, one of the functional ingredients listed in the Hybrid Coatings Technologies/Nanotech Industries Green Polyurethane™ patent has lower exposure potential *via* air compared to the Priority Products, but no data are available for the other functional ingredient. Moreover, no data are available on the functional ingredients' exposure potential in water, soil, or sediment for this product. Lastly, it would be preferable to compare exposure data for the Priority Products and possible alternatives as formulated (*i.e.*, A-side, B-side), because the individual ingredients may influence each other's properties when combined. Unfortunately, no product-level exposure information is available at this time for any of the possible alternatives.

Section 5 concludes with a discussion of product cost as well as external (*i.e.*, public health and environmental), and internal costs for the Priority Products and the potential alternatives. We could not evaluate product costs between the Priority Products and most of the potential alternatives, because most of the potential alternatives are not commercially available. Two of the lower-exposure approaches are commercially available and their costs are not markedly different than those of the Priority Products. For example, installing Profill System may be more expensive than the standard Priority Products, due to the increased costs associated with labor and the additional products necessary to apply Profill System, but less trimming is required for this product, which could be a cost savings.

Regarding external costs, insufficient data are available to quantify public health costs for treating occupational asthma associated with MDI/pMDI exposure from the Priority Product. No studies that could be used to quantify the number of occupational asthma cases among workers exposed to any of the Priority Products were found; studies of occupational asthma exist, but none provide the level of specificity needed for the current evaluation. For example, a 2015 study of occupational asthma cases in several states, including California, did not identify any cases of occupational asthma that could be clearly attributed to MDI/pMDI exposure from SPF application, making reliable cost estimation impossible. Without an estimate of public health costs associated with the Priority Products, estimates of corresponding costs associated with the possible alternatives are not useful. We also attempted to assess the costs of environmental waste management related to the

Priority Products and the potential alternatives. However, data are not available to support an analysis of such costs, either for the Priority Products or any of the possible alternatives.

The REs attempted to quantify the internal costs of developing and bringing to market a non-MDI-based alternative product for smaller specialty and larger multinational companies. It was estimated that the internal costs associated with the research, design, and development of new manufacturing capacity to bring an alternative product to market could easily reach over $5M per RE per product. The REs anticipate that the total SPF market in California is less than $100M. With 17 REs, the cost to develop a new alternative could easily cost $85M, plus costs associated with new equipment and developing new manufacturing facilities. It is the REs' position that, given the size of the California SPF market, the costs associated with implementing a new alternative, and the inability to quantify a beneficial impact of using alternative SPF products on public health, implementing a new safer alternative to the Priority Products is not economically feasible.

- **Section 6** presents the conclusions of the Abridged AA. As noted above, our analysis indicates that there are no alternatives to the Priority Products with sufficient data to support a full and accurate AA according to the SCP regulations' requirements. This section also discusses the lack of an established AAT or acceptable exposure reduction that the REs can use to identify a safer alternative to the Priority Products. Additionally, it is the REs' position that any safer alternative, as defined by the SCP regulations, would need to replace all of the existing functions of the Priority Products in a single product type. Implementing a niche alternative for only one application (*e.g.*, open-cell SPF in a wall cavity) or one product (*e.g.*, 2-lb SPF) is outside of the scope of the REs' business model and would likely be economically infeasible. It could also negatively impact the effectiveness of worker safety training programs.

- **Section 7** discusses proposed regulatory responses given that no suitable safer alternatives to the Priority Products were identified. It details product information for consumers, including workers. To improve product stewardship practices, high-pressure SPF manufacturers also propose to include a statement on product labels or bunghole covers to state that users must take the free online CPI Spray Polyurethane Foam Chemical Health and Safety Training available at www.spraypolyurethane.org or have successfully passed the manufacturer's installer training before opening the product. Low-pressure SPF manufactures also propose to include a statement on product labels or a tag adhered to the product application equipment that must be removed prior to use that states that users must take the free online CPI Spray Polyurethane Foam Chemical Health and Safety Training available at www.spraypolyurethane.org before opening the product. Lastly, this section also includes a proposal from the REs to engage in a research program as required by the SCP regulations. It also details a potential research plan to satisfy the regulations' funding of green chemistry requirements.

- **Section 8** discusses uncertainties encountered in preparing this Abridged AA report and the potential implications these may have for the results of the Abridged AA.

- **Section 9** presents the report references.

- **Appendices** providing some of the supporting data and other supporting information are included at the end of the report.

1 Preparer Information

Responsible Entities (REs) Information:

First Name	Jon
Last Name	Purcell
Company	Carlisle Spray Foam Insulation (formerly Accella Polyurethane Systems)
Business Type	Manufacturer
Email	Jon.Purcell@carlislePS.com
Phone	314-764-2814
Website	https://www.carlislesfi.com
Address	2500 Adie Road, Maryland Heights, MO 63043

First Name	Peter
Last Name	Bartell
Company	A&B Filling Inc.
Business Type	Manufacturer
Email	peter@abfilling.com
Phone	262-754-8060
Website	(A&B Filling Inc. does not have a website)
Address	5500 S. Westridge Dr. New Berlin, WI 53151

First Name	Chris
Last Name	Janzen
Company	BASF Corporation
Business Type	Manufacturer
Email	Chris.Janzen@basf.com
Phone	416-674-2777
Website	www.spf.basf.com
Address	BASF Canada Inc., 10 Constellation Court, M9W 1K1, Toronto, Canada

First Name	Neema
Last Name	Toolaabee
Company	DAP Products Inc.
Business Type	Manufacturer
Email	ntoolaabee@dap.com
Phone	410-779-2338
Website	www.dap.com
Address	2400 Boston Street, Suite 200, Baltimore, MD 21224

First Name	Doug
Last Name	Brady
Company	Demilec[1]
Business Type	Manufacturer
Email	doug.brady@demilec.com
Phone	817-640-4900
Website	www.demilec.com
Address	3315 East Division Street, Arlington, TX 76011

Note:
(1) Icynene-Lapolla and Demilec are now part of the Huntsman group of companies (Huntsman Building Solutions). However, they asked to be listed separately for the purpose of this Abridged AA.

First Name	Lisa
Last Name	Massaro
Company	DuPont
Business Type	Manufacturer
Email	lisa.m.massaro@dupont.com
Phone	989-638-4248
Website	www.dupont.com
Address	Performance Building Solutions, 1501 Larkin Center Drive, 200 Building, Midland, MI 48640

First Name	Nilo
Last Name	Noxon
Company	Firestone Building Products
Business Type	Manufacturer
Email	NoxonNilo@bfusa.com
Phone	262-832-0748
Website	www.firestonebpco.com
Address	1245 Chapman Drive, Waukesha, WI 53186

First Name	Don
Last Name	Schumacher
Company	Foam Supplies, Inc.
Business Type	Manufacturer
Email	dschumacher@foamsupplies.com
Phone	314-344-3330
Website	www.foamsupplies.com
Address	4387 North Rider Trail, Earth City, MO 63045

First Name	Eric
Last Name	Montie
Company	General Coatings Manufacturing Corp.
Business Type	Manufacturer
Email	eric@generalcoatings.net
Phone	559-495-4004
Website	https://www.generalcoatings.net
Address	1220 East North Avenue, Fresno, CA 93725

First Name	Whitney
Last Name	Randall
Company	Henry Company LLC
Business Type	Manufacturer
Email	WRandall@henry.com
Phone	484-557-1247
Website	www.henry.com
Address	999 North Pacific Coast Highway, Suite 800, El Segundo, CA 90245

First Name	Sandy
Last Name	Gump
Company	ICP Adhesives & Sealants
Business Type	Manufacturer
Email	sgump@icpadhesives.com
Phone	330-753-4585
Website	www.handifoam.com
Address	2775 Barber Road, Norton, OH 44203

First Name	Steve
Last Name	Williams
Company	Icynene-Lapolla[1]
Business Type	Manufacturer
Email	swilliams@icynene-lapolla.com
Phone	281-219-4100
Website	www.icynene.com or www.lapolla.com
Address	15402 Vintage Parkway East, Suite 322, Houston, TX 77032

Note:
(1) Icynene-Lapolla and Demilec are now part of the Huntsman group of companies (Huntsman Building Solutions). However, they asked to be listed separately for the purpose of this Abridged AA.

First Name	Kathryn
Last Name	Miks
Company	Johns Manville
Business Type	Manufacturer
Email	Kathy.Miks@jm.com
Phone	303-978-2000
Website	www.jm.com
Address	717 17th Street, Denver, CO 80202

First Name	Jason
Last Name	Hoerter
Company	Barnhardt Manufacturing Company dba NCFI® Polyurethanes
Business Type	Manufacturer
Email	Jason.Hoerter@ncfi.net
Phone	800-346-8229
Website	www.ncfi.net
Address	71515 Carter Street, Mount Airy, NC 27030

First Name	Jose
Last Name	Luna
Company	SES Foam LLC
Business Type	Manufacturer
Email	JLuna@SESFoam.com
Phone	713-239-0252
Website	www.sesfoam.com or www.sucraseal.com
Address	4008 Louetta Road #538, Spring, TX 77388

First Name	Paul
Last Name	Warren
Company	SWD Urethanes
Business Type	Manufacturer
Email	Paul.Warren@swdurethane.com
Phone	800-828-1394
Website	www.swdurethane.com
Address	540 South Drew Street, Mesa, AZ 85210

First Name	Nelson
Last Name	Medina
Company	Rhino Linings Corporation
Business Type	Manufacturer
Email	nmedina@rhinolinings.com
Phone	858-410-6007
Website	www.rhinolinings.com
Address	9747 Business Park, San Diego CA 92131

Other Involved Parties:

First Name	Stephen
Last Name	Wieroniey
Organization	American Chemistry Council
Involvement	Coordinating the Alternatives Analysis (AA) effort

First Name	Tom
Last Name	Lewandowski
Organization	Gradient
Involvement	Preparing Abridged AA report

First Name	Jiaru
Last Name	Zhang
Organization	Gradient
Involvement	Preparing Abridged AA report

This Abridged AA report was funded by the American Chemistry Council's Spray Foam Coalition (SFC). SFC member companies are as follows.*

1. A&B Filling Inc./RHH Foam Systems
2. Albemarle**

3. Arkema**
4. BASF
5. Carlisle Spray Foam Insulation (formerly Accella Polyurethane Systems)
6. Chemours**
7. COIM USA, Inc.**
8. Covestro**
9. Creative Polymer Solutions
10. DAP Products Inc.
11. Demilec, part of the Huntsman group of companies
12. DuPont, Performance Building Solutions (formerly Dow Building Solutions)
13. Evonik Corporation**
14. Firestone
15. Foam Supplies, Inc.
16. General Coatings
17. Graco, Inc.**
18. Henry Company
19. Honeywell**
20. ICL-IP**
21. ICP Adhesives and Sealants
22. Icynene-Lapolla, part of the Huntsman group of companies
23. Johns Manville
24. NCFI Polyurethanes
25. Rhino Linings Corporation
26. SES Foam
27. Stepan**
28. SWD Urethane
29. Wanhua Chemical (America) Co., LTD**

*Solvay Fluorides is no longer a member as of 2020; however, they were a member in 2019, when the original report was developed.
**Associate Members (suppliers to the SPF industry).

Certification and Signatures

Certification of the Abridged AA Report is included in Appendix D or will be done *via* online signature *via* the CalSAFER website during AA submission.

2 Responsible Entity and Supply Chain Information

Manufacturer(s), Importers, and Consortium Participants:

Please see information under responsible entities (REs) in Section 1.

Manufacturer(s), Importer(s), and/or Distributor(s) Listed on the Priority Products' Labels:

These data are regarded as confidential business information (CBI) for each consortium participant. A separate Appendix B will be submitted by each consortium participant and marked as CBI. Information will contain manufacturers', importers', and /or distributors' first and last name, company, email address, phone number, website, and address.

Purchasers of Priority Products:

These data are regarded as CBI for each consortium participant. A separate Appendix B will be submitted by each consortium participant and marked as CBI. Information will contain purchasers' first and last name, company, email address, phone number, website, and address.

Manufacturer(s) and/or Importer(s) Retail Sales Outlets:

Not applicable. The manufacturers of the Priority Products do not have their own retail sales outlets. Some spray polyurethane foam (SPF) products (*i.e.*, low-pressure SPF) are sold *via* third-party retailers, and other SPF products are restricted for use by commercial applicators who purchase these products directly from the manufacturer or through distributors.

3 Priority Products Information

3.1 Priority Products Made by Responsible Entities Participating in this Abridged Alternatives Analysis Report

This RE consortium comprises systems houses[1] of low- and high-pressure two-component SPF products for insulation and roofing containing unreacted methylene diphenyl diisocyanate (MDI) that intend to continue selling the Priority Products in California. Note that MDI is not used as a discrete chemical in the Priority Products. SPF formulations are based on pMDI (defined below). The Priority Products listed on each RE's Priority Product Notifications are shown in Table 3.1. Product safety data sheets (SDSs) for each of these products are provided in Appendix A and will be submitted individually by each RE. Appendix A will include any non-CBI SDSs, if any, or a statement that all of an RE's SDSs are being claimed as CBI. Some REs will submit Appendix A1, which will be an addendum to Appendix A containing SDSs that are considered CBI (*e.g.*, private label products that involve disclosing confidential sales relationships). These SDSs are considered CBI to protect the business relationship.

3.2 Chemical(s) of Concern for the Priority Products

The chemicals of concern for the Priority Products are 4,4'-methylene diphenyl diisocyanate (4,4'-MDI), Chemical Abstract Service Registry Number (CAS No.) 101-68-8, and generic methylene diphenyl diisocyanate, mixed isomers, CAS No. 26447-40-5 (CalDTSC, 2014). According to the California Department of Toxic Substances Control (CalDTSC) Revised Priority Products Profile, products using other diisocyanates, such as toluene diisocyanates (TDIs) and hexamethylene-1,6-diisocyanate (HDI), as well as one-component SPF systems typically sold in cans are not included in the scope of this Abridged AA (CalDTSC, 2014).

SPF products are not formulated with 4,4'-MDI or generic methylene diphenyl diisocyanates, mixed isomers, as discrete chemical ingredients. Rather, SPF products use polymeric MDI (pMDI; CAS No. 9016-87-9), which is produced, marketed, and formulated into SPF products as a technical mixture of monomeric and oligomeric MDI constituents, including 4,4'-MDI. Using the higher-molecular-weight pMDI inherently reduces the potential for exposure to unreacted MDI during SPF application. The generic structure below is often used to represent the composition of pMDI (Figure 3.1).

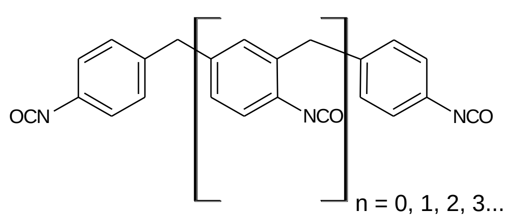

Figure 3.1 Generic Structure of pMDI

[1] The term "systems houses" is used to designate the manufacturers that supply the formulated A-side and B-side of the SPF to applicators. Systems houses can be distinguished from the chemical suppliers that provide the pMDI, polyols, and other chemicals to the systems houses.

3.3 Function of the Priority Products

The Priority Products can serve as all-in-one thermal and acoustic insulation, an air barrier, a vapor retarder, and, in some cases, a moisture barrier for commercial and residential walls, basements, and roofs (SFC, 2020a). There are three types of two-component high-pressure SPF products – open-cell 0.5-lb/ft^3 SPF and closed-cell 2- and 3-lb/ft^3 SPF[2] – which should each be considered a separate product. Closed-cell SPFs provide more resistance to heat transfer (*i.e.*, higher R-values), better moisture resistance, and better structural support compared to open-cell SPFs, whereas open-cell SPFs have greater flexibility and are better acoustic insulators. In addition to these properties, SPF also helps increase building strength and prevents the entry of pollen, dust, and insects into the building where it is applied (SFC, 2020a,b).

[2] The densities given are approximate. For example, 2-lb foam can have a measured density ranging from 1.75-2.5 lbs.

Table 3.1 Manufacturers of Low- and High-Pressure Two-Component SPF Products Containing Unreacted MDI Currently for Sale in California

Manufacturer Name	Product Name	Name on SDS		Name on PPN
		A-Side	B-Side	
Accella Polyurethane Systems[1]	FOAMSULATE 220 SERIES	POLYURETHANE FOAM A-COMPONENT	FOAMSULATE 220 SERIES	FOAMSULATE 220 SERIES
	FOAMSULATE 210 SERIES	POLYURETHANE FOAM A-COMPONENT	FOAMSULATE 210 SERIES	Foamsulate 210
	Foamsulate 50 NIB	POLYURETHANE FOAM A-COMPONENT	Foamsulate 50 NIB	Foamsulate 50 NIB
	BAYSEAL OC	POLYURETHANE FOAM A-COMPONENT	BAYSEAL OC	Bayseal OC
	BAYSEAL OC X	POLYURETHANE FOAM A-COMPONENT	BAYSEAL OC X	Bayseal OC X
	BAYSEAL CC X	POLYURETHANE FOAM A-COMPONENT	BAYSEAL CC X	Bayseal CCX
	BAYSEAL 2.7 Series	POLYURETHANE FOAM A-COMPONENT	BAYSEAL 2.7 Series, BAYSEAL 3.0 Series	Bayseal 2.7
	BAYSEAL 3.0 Series	POLYURETHANE FOAM A-COMPONENT	BAYSEAL 2.7 Series, BAYSEAL 3.0 Series	Bayseal 3.0
	QuadFoam NatureSeal OCX	POLYURETHANE FOAM A-COMPONENT	NatureSeal OCX	QuadFoam Natureseal OCX
	Bayseal OC HY	POLYURETHANE FOAM A-COMPONENT	Bayseal OC HY	Bayseal OC HY
	QuadFoam 2.0	POLYURETHANE FOAM A-COMPONENT	QuadFoam 2.0	QuadFoam 2.0
	QuadFoam 500	POLYURETHANE FOAM A-COMPONENT	QuadFoam 500	QuadFoam 500
	Premipour 202M	POLYURETHANE FOAM A-COMPONENT	Premipour 202M	Premipour 202M
	PREMISEAL 40 SERIES	POLYURETHANE FOAM A-COMPONENT	PREMISEAL 40 SERIES	Premiseal 40
	PREMISEAL 60 SERIES	POLYURETHANE FOAM A-COMPONENT	PREMISEAL 60 SERIES	Premiseal 60
	PREMISEAL 70 SERIES[2]	POLYURETHANE FOAM A-COMPONENT	PREMISEAL 70	Premiseal 70
	PREMISEAL 80 SERIES[2]	POLYURETHANE FOAM A-COMPONENT	PREMISEAL 80	Premiseal 80

Manufacturer Name	Product Name	Name on SDS		Name on PPN
		A-Side	B-Side	
Accella Polyurethane Systems[1]	PREMISEAL 250 SERIES	POLYURETHANE FOAM A-COMPONENT	Premiseal 250 Series	Premiseal 250
	PREMISEAL 255 SERIES	POLYURETHANE FOAM A-COMPONENT	Premiseal 255 Series	Premiseal 255
	PREMISEAL 280 SERIES	POLYURETHANE FOAM A-COMPONENT	Premiseal 280 Series	Premiseal 280
	PREMISEAL 285 SERIES	POLYURETHANE FOAM A-COMPONENT	Premiseal 285 Series	Premiseal 285
	PREMISEAL 300 SERIES	POLYURETHANE FOAM A-COMPONENT	Premiseal 300 Series	Premiseal 300
	PREMIR+ 60 SERIES	POLYURETHANE FOAM A-COMPONENT	PREMIR+ 60 SERIES	PremiR 60
	PREMIR+ 40 SERIES	POLYURETHANE FOAM A-COMPONENT	PREMIR+ 40 SERIES	PremiR+ 40
	FOAMSULATE CLOSED CELL SERIES	POLYURETHANE FOAM A-COMPONENT	FOAMSULATE CLOSED CELL ARCTIC; FOAMSULATE CLOSED CELL REGULAR; FOAMSULATE CLOSED CELL WINTER	Foamsulate Closed Cell
	FOAMSULATE HFO SERIES	POLYURETHANE FOAM A-COMPONENT	FOAMSULATE HFO REGULAR; FOAMSULATE HFO WINTER	Foamsulate HFO
	FOAMSULATE 50 HY	POLYURETHANE FOAM A-COMPONENT	FOAMSULATE 50 HY	Foamsulate 50 HY
	FOAMSULATE 50	POLYURETHANE FOAM A-COMPONENT	FOAMSULATE 50	Foamsulate 50
	FOAMSULATE OCX	POLYURETHANE FOAM A-COMPONENT	FOAMSULATE OCX	Foamsulate OCX
	FOAMSULATE 70	POLYURETHANE FOAM A-COMPONENT	FOAMSULATE 70	Foamsulate 70

Manufacturer Name	Product Name	Name on SDS		Name on PPN
		A-Side	B-Side	
Accella Polyurethane Systems[1]	SEALTITE PRO CLOSED CELL SERIES	POLYURETHANE FOAM A-COMPONENT	SEALTITE PRO CLOSED CELL ARCTIC; SEALTITE PRO CLOSED CELL REGULAR; SEALTITE PRO CLOSED CELL WINTER	SealTite PRO Closed Cell
	SEALTITE PRO HIGH YIELD	POLYURETHANE FOAM A-COMPONENT	SEALTITE PRO HIGH YIELD	SealTite PRO High Yield
	SEALTITE PRO NO MIX	POLYURETHANE FOAM A-COMPONENT	SEALTITE PRO NO MIX	SealTite PRO No Mix
	SEALTITE PRO NO TRIM	POLYURETHANE FOAM A-COMPONENT	SEALTITE PRO NO TRIM 21	SEALTITE PRO NO TRIM
	SEALTITE PRO OCX	POLYURETHANE FOAM A-COMPONENT	SEALTITE PRO OCX	SealTite PRO OCX
	SEALTITE PRO ONE ZERO SERIES	POLYURETHANE FOAM A-COMPONENT	SEALTITE PRO ONE ZERO REGULAR; SEALTITE PRO ONE ZERO WINTER	SealTite PRO One Zero
	SEALTITE PRO OPEN CELL	POLYURETHANE FOAM A-COMPONENT	SEALTITE PRO OPEN CELL	SealTite PRO OPEN CELL
A&B Filling Inc.	Brand A Product 1	CBI	CBI	CBI
	Brand B Product 2	CBI	CBI	CBI
	Brand C Product 3	CBI	CBI	CBI
	Brand D Product 4	CBI	CBI	CBI
BASF Corp.	Elastospray 81255 SERIES	ELASTOSPRAY® 8000A ISOCYANATE	ELASTOSPRAY® 81255 F RESIN; ELASTOSPRAY® 81255 R RESIN; ELASTOSPRAY® 81255 S RESIN; ELASTOSPRAY® 81255 SAZ RESIN; ELASTOSPRAY 81255 XF RESIN	Elastospray 81255
	Elastospray 81285 SERIES	ELASTOSPRAY® 8000A ISOCYANATE	ELASTOSPRAY® 81285 F RESIN; ELASTOSPRAY® 81285 R RESIN; ELASTOSPRAY® 81285 S RESIN; ELASTOSPRAY® 81285 SAZ RESIN; ELASTOSPRAY® 81285 XF RESIN	Elastospray 81285

Manufacturer Name	Product Name	Name on SDS		Name on PPN
		A-Side	B-Side	
BASF Corp.	Elastospray 81305 SERIES	ELASTOSPRAY® 8000A ISOCYANATE	ELASTOSPRAY® 81305 F RESIN; ELASTOSPRAY® 81305 R RESIN; ELASTOSPRAY® 81305 S RESIN; ELASTOSPRAY® 81305 SAZ RESIN; ELASTOSPRAY® 81305 XF RESIN	Elastospray 81305
	Elastospray 8000A	ELASTOSPRAY® 8000A ISOCYANATE	N/A	ELASTOSPRAY 8000A
	ENERTITE G	ELASTOSPRAY® 8000A ISOCYANATE	ENERTITE G	ENERTITE G
	ENERTITE NM	ELASTOSPRAY® 8000A ISOCYANATE	ENERTITE NM	ENERTITE NM
	FE 348-2.5 SERIES	ELASTOSPRAY® 8000A ISOCYANATE	FE 348-2.5F B-RESIN; FE 348-2.5R B-RESIN; FE 348-2.5S B-RESIN; FE 348-2.5SAZ B-RESIN; FE 348-2.5XF B-RESIN	FE 348-2.5
	FE 348-2.8 SERIES	ELASTOSPRAY® 8000A ISOCYANATE	FE 348-2.8F B-RESIN; FE 348-2.8R B-RESIN; FE 348-2.8S B-RESIN; FE 348-2.8SAZ B-RESIN; FE 348-2.8XF B-RESIN	FE 348-2.8
	FE 348-3.0 SERIES	ELASTOSPRAY® 8000A ISOCYANATE	FE 348-3.0F B-RESIN; FE 348-3.0R B-RESIN; FE 348-3.0S B-RESIN; FE 348-3.0SAZ B-RESIN; FE 348-3.0XF B-RESIN	FE 348-3.0
	SKYTITE 2.5	ELASTOSPRAY® 8000A ISOCYANATE	SKYTITE C1-2.5R RESIN	SKYTITE 2.5
	SKYTITE 2.8	ELASTOSPRAY® 8000A ISOCYANATE	SKYITE C1 – 2.8R RESIN	SKYTITE 2.8
	SKYTITE 3.0	ELASTOSPRAY® 8000A ISOCYANATE	SKYTITE C1 -3.0R RESIN	SKYTITE 3.0
	SPRAYTITE 158	ELASTOSPRAY® 8000A ISOCYANATE	SPRAYTITE 158 – LDM	SPRAYTITE 158

Manufacturer Name	Product Name	Name on SDS		Name on PPN
		A-Side	B-Side	
BASF Corp.	SPRAYTITE 178 SERIES	ELASTOSPRAY® 8000A ISOCYANATE	SPRAYTITE® 178-M B-RESIN; SPRAYTITE® 178-XF B-RESIN; SPRAYTITE® 178-F B-RESIN	SPRAYTITE 178
	SPRAYTITE 180 SERIES	ELASTOSPRAY® 8000A ISOCYANATE	SPRAYTITE® 180-F B-RESIN; SPRAYTITE 180-XF B-RESIN	SPRAYTITE 180
	SPRAYTITE 81206 SERIES	ELASTOSPRAY® 8000A ISOCYANATE	SPRAYTITE 81206 FR F RESIN; SPRAYTITE® 81206 FR XF RESIN	SPRAYTITE 81206
	SPRAYTITE SP	ELASTOSPRAY® 8000A ISOCYANATE	SPRAYTITE SP XF B-RESIN	SPRAYTITE SP
	WALLTITE US SERIES	ELASTOSPRAY® 8000A ISOCYANATE	WALLTITE US R RESIN; WALLTITE® US F RESIN; WALLTITE® US W RESIN	WALLTITE US
	WALLTITE HP+	ELASTOSPRAY® 8000A ISOCYANATE	WALLTITE HP+ W RESIN	WALLTITE HP+
	BASF CBI - #1	CBI	CBI	BASF CBI #1
	BASF CBI - #2	CBI	CBI	BASF CBI #2
	BASF CBI - #3	CBI	CBI	BASF CBI #3
	BASF CBI - #4	CBI	CBI	BASF CBI #4
	BASF CBI - #5	CBI	CBI	BASF CBI #5
	BASF CBI - #6	CBI	CBI	BASF CBI #6
	BASF CBI - #7	CBI	CBI	BASF CBI #7
	BASF CBI - #8	CBI	CBI	BASF CBI #8
	BASF CBI - #9	CBI	CBI	BASF CBI #9
	BASF CBI - #10	CBI	CBI	BASF CBI #10
	BASF CBI - #11	CBI	CBI	BASF CBI #11
	BASF CBI - #12	CBI	CBI	BASF CBI #12
	BASF CBI - #13	CBI	CBI	BASF CBI #13
	BASF CBI - #14	CBI	CBI	BASF CBI #14
	BASF CBI - #15	CBI	CBI	BASF CBI #15
	BASF CBI - #16	CBI	CBI	BASF CBI #16
	BASF CBI - #17	CBI	CBI	BASF CBI #17
	BASF CBI - #18	CBI	CBI	BASF CBI #18

Manufacturer Name	Product Name	Name on SDS		Name on PPN
		A-Side	B-Side	
DAP Products, Inc.	Touch n' Seal Fire-Rated 1.75 PCF Slow Rise Polyurethane Foam Sealant	Touch n Seal 1.75 PCF Slow Rise 2K Closed Cell Polyurethane Foam Kit A-Side	Touch n Seal 1.75 PCF Slow Rise 2K Closed Cell Polyurethane Foam Kit B-Side	Touch n Seal Fire-Rated 1.75 PCF Slow Rise Polyurethane Foam Sealant
	Touch n' Seal 1.75 PCF ICC Closed Cell Polyurethane Foam Sealant	Touch n Seal 1.75 PCF Fire-Rated Standard ICC Closed Cell 2K Foam Kit A-Side	Touch n Seal 1.75 PCF Fire-Rated Standard ICC Closed Cell 2K Foam Kit B-Side	Touch n Seal Fire-Rated 1.75 PCF ICC Closed Cell Polyurethane Foam Sealant
	Touch n' Seal 2.0 PCF Fire-Rated Polyurethane Foam Sealant	Touch n Seal 2.0 PCF Fire-Rated Standard 2K Closed Cell PU Foam Kit A-side	Touch n Seal 2.0 PCF Fire-Rated Standard 2K Closed Cell PU Foam Kit B-side	Touch n Seal Fire-Rated 2.0 PCF Polyurethane Foam Sealant
	Touch n' Seal 3.0 PCF High Density Closed Cell Polyurethane Foam Sealant	Touch n Seal 3.0 PCF Closed Cell 2K PU Foam Kit A-side	Touch n Seal 3.0 PCF Closed Cell 2K PU Foam Kit B-side	Touch n Seal 3.0 PCF High Density Closed Cell Polyurethane Foam Sealant
	Touch n' Seal Mine Foam Sealant	Touch n Seal Mine Sealant 2K PU Foam Kit A-side	Touch n Seal Mine Sealant 2K PU Foam Kit B-side	Touch n Seal Polyurethane Mine Foam Sealant
	Touch n' Foam Professional Fire-Rated 1.75 PCF CCMC Closed Cell Polyurethane Foam Sealant	Touch n Foam Professional 1.75 PCF CCMC closed cell 2k system 600 PU Foam Kit A-side	Touch n Foam Professional 1.75 PCF CCMC closed cell 2k system 600 PU Foam Kit B-side	Touch n Foam Professional Fire-Rated 1.75 PCF CCMC closed Cell Polyurethane Foam Sealant
	Touch n' Foam Fire-Rated 1.75 PCF Closed Cell ICC Polyurethane Foam Sealant	Touch n Foam Professional 1.75 PCF ICC Closed Cell 2K System 600 PU Foam Kit A-Side	Touch n Foam Professional 1.75 PCF ICC Closed Cell 2K System 600 PU Foam Kit B-Side	Touch n Foam Fire-Rated 1.75 PCF Closed Cell ICC Polyurethane Foam Sealant
	Touch n' Seal Fire-Rated Low Density 1.0 PCF Open Cell Polyurethane Foam Sealant	Touch n Seal Low Density 1.0 PCF Standard Open Cell 2K PU Foam Kit A-Side	Touch n Seal Low Density 1.0 PCF Standard Open Cell 2K PU Foam Kit B-Side	Touch n Seal Fire-Rated 1.0 PCF Low Density Open Cell Polyurethane Foam Sealant
	Touch n' Seal 1.75 PCF Fire Rated PCF CCMC Closed Cell Polyurethane Foam Sealant	Touch n Seal 1.75 PCF Fire-Rated Standard CCMC Closed Cell 2K PU Foam Kit A-Side	Touch n Seal 1.75 PCF Fire-Rated Standard CCMC Closed Cell 2K PU Foam Kit B-Side	Touch n Seal Fire-Rated 1.75 PCF CCMC closed Cell Polyurethane Foam

Manufacturer Name	Product Name	Name on SDS		Name on PPN
		A-Side	B-Side	
Demilec	Agribalance	A-PMDI	Agribalance B-Side	Agribalance
	Demilec APX Series	A-PMDI	Demilec APX 1.2; Demilec APX 2.0	Demilec APX
	Heatlok HFO High Lift	A-PMDI	Heatlok HFO High Lift B-Side	Heatlok HFO High Lift
	Heatlok HFO Pro	A-PMDI	Heatlok HFO Pro B-Side	Heatlok HFO Pro
	Heatlok Soy 200+	A-PMDI	Heatlok Soy 200 Plus B-Side	Heatlok 200+
	Heatlok XT	A-PMDI	Heatlok XT B-Side	Heatlok XT
	Sealection 500	A-PMDI	Sealection 500 B-Side	Sealection 500
DuPont	FrothPak™ Sealant and Insulation	FROTH-PAK™ ISO INT AF HFC	FROTH-PAK™ Polyol INT 1.75 HFC Blend; FROTH-PAK™ Class A Polyol INT Blend	FROTH-PAK(TM) Sealant and Insulation
	FrothPak™ Ultra Insulation	FROTH-PAK™ Ultra 17gal REF ISO Spray Foam Sealant	FROTH-PAK™ Ultra 17gal REF Polyol Spray Foam Sealant	FROTH-PAK(TM) ULTRA Insulation
	Styrofoam™ Dow 3019 with CM2045	DOW™ 3019 Isocyanate	STYROFOAM™ SPF CM 2045 Polyol 55gal	STYROFOAM™ CM Series Spray Polyurethane Foam
Firestone	F1800 – GacoTrenchFoam – Polyol Component B	ISOCYANATE - ISO COMPONENT A	GACOTRENCHFOAM - POLYOL COMPONENT B F1800, F1800-55, F1800-275	F1800 – GacoTrenchFoam – POLYOL COMPONENT B
	F-CF2030 – GacoPourFoam CF2030 – Polyol Component B	ISOCYANATE - ISO COMPONENT A	GacoPourFoam CF2030 - POLYOL COMPONENT B	F-CF2030 – GacoPourFoam CF2030 – POLYOL COMPONENT B
	FB28-120 – GacoFlashFoam – Component A & B	FB28-120 GacoFlashFoam - component A	FB28-120 GacoFlashFoam - component B	FB28-120 – GacoFlashFoam – Component A & B
	F10000 – GacoToughFoam – Polyol Component B	ISOCYANATE - ISO COMPONENT A	GacoToughFoam - POLYOL COMPONENT B	F10000 – GacoToughFoam – POLYOL COMPONENT B
	F183M – Gaco 183M– Polyol Component B	ISOCYANATE - ISO COMPONENT A	GACO 183M - POLYOL COMPONENT B	F183M – Gaco 183M– POLYOL COMPONENT B
	F1850R – GacoOnePass – Polyol Component B	ISOCYANATE - ISO COMPONENT A	GacoOnePass - POLYOL COMPONENT B	F1850R – GacoOnePass – POLYOL COMPONENT B
	F052N – Gaco 052N GacoInsulBarrier – Polyol Component B	ISOCYANATE - ISO COMPONENT A	GACO 052N - POLYOL COMPONENT B	F052N – Gaco 052N GacoInsulBarrier – POLYOL COMPONENT B

Manufacturer Name	Product Name	Name on SDS		Name on PPN
		A-Side	B-Side	
Firestone	F5001 –GacoFireStop 2 – Polyol Component B	ISOCYANATE - ISO COMPONENT A	GacoFireStop2 - POLYOL COMPONENT B	F5001 –GacoFireStop2 – POLYOL COMPONENT B
	F4500R – GacoEZSpray – Polyol Component B	ISOCYANATE - ISO COMPONENT A	F4500R, F4500R-450, F4500R-2340	F4500R – GacoEZSpray – POLYOL COMPONENT B
	FR6500R – GacoProFill – Polyol Component B	ISOCYANATE - ISO COMPONENT A	GacoProFill - POLYOL COMPONENT B FR6500R, FR6500R-5, FR6500R-55, FR6500R-480	FR6500R – GacoProFill – POLYOL COMPONENT B
	F1880R – GacoOnePass Low GWP – Polyol Component B	ISOCYANATE - ISO COMPONENT A	F1880R POLYOL COMPONENT B	F1880R – GacoOnePass Low GWP – POLYOL COMPONENT B
	F2733R – GacoRoofFoam – Polyol Component B	ISOCYANATE - ISO COMPONENT A	GacoRoofFoam - POLYOL COMPONENT B F2733R, F2733R-55	F2733R – GacoRoofFoam – POLYOL COMPONENT B
	F2780 – Polyol Component B	ISOCYANATE - ISO COMPONENT A	F2780 - POLYOL COMPONENT B F2780, F2780-500	F2780 – POLYLOL COMPONENT B
	ISO – Isocyanate – Iso Component A	ISOCYANATE - ISO COMPONENT A	N/A	ISO – ISOCYANATE – ISO COMPONENT A
General Coatings Manufacturing Corp.	Brand A 1, 2.5	CBI	CBI	CBI
	Brand A 2, 2.7	CBI	CBI	CBI
	Brand A 3, 3.0	CBI	CBI	CBI
	Brand B 1, 2.5	CBI	CBI	CBI
	Brand B 2, 2.7	CBI	CBI	CBI
	Brand B 3, 3.0	CBI	CBI	CBI
	Ultra-Thane 050	Ultra-Thane 050, A-Side	Ultra-Thane 050, B-Side	050
	Ultra-Thane 050 OCX	Ultra-Thane 050X, A-Side	Ultra-Thane 050X, B-Side	050 OCX
	Ultra-Thane 170 Pour Foam	Ultra-Thane 170 A-Side	Ultra-Thane 170 B-Side	Ultra-Thane 170
	Ultra-Thane 230-2.0	Ultra-Thane 230, A-Side	Ultra-Thane 230, B-Side	230-2.0
	Ultra-Thane 230-2.5, 2.7, and 3.0 Roof Foam	Ultra-Thane 230, A-Side	Ultra-Thane 230, B-Side	230-2.5, 2.7, AND 3.0 ROOF FOAM
	Universal Polymers Corp 2.0	UPC Polymeric MDI, A-Side	UPC 2.0, B-Side	2.0
	Universal Polymers Corp 500	UPC Polymeric MDI, A-Side	UPC 500, B-Side	500
	Universal Polymers Corp 500 OCX	UPC Polymeric MDI, A-Side	UPC 500 OCX, B-Side	500 OCX

Manufacturer Name	Product Name	Name on SDS		Name on PPN
		A-Side	B-Side	
Henry Company LLC	Permax Closed-cell Foam Insulation Series	COMPONENT A	RT-2015-2.0-W; RT-2035-B-2.5-R; RT-2045-B-1.8-W	Permax Closed-cell Foam Insulation
ICP Adhesives & Sealants	Handi-Foam® E84 Spray Foam	LOW PRESSURE POLYURETHANE FOAM A-SIDE COMPONENT (134a); Handi-Foam® E84 Class 1, Handi-Foam® Quick Cure, Handi-Foam® SPF Roof Patch, Handi-Foam® Commercial Vehicle, Handi-Foam® Sound Barrier, Handi-Foam® Air Seal, Handi-Foam® Low Density, Hand-Foam® Slow Rise, Silent Seal® SA, and Handi-Foam® Black	LOW PRESSURE POLYURETHANE FOAM B-SIDE COMPONENT (134a); Handi-Foam® E84 Class 1, Handi-Foam® Quick Cure, Handi-Foam® SPF Roof Patch, Handi-Foam® Air Seal, Hand-Flow® Slow Rise, Handi-Foam® Black and Silent Seal® SA	HandiFoam E84 Spray Foam
	Handi-Foam® Quick Cure	LOW PRESSURE POLYURETHANE FOAM A-SIDE COMPONENT (134a); Handi-Foam® E84 Class 1, Handi-Foam® Quick Cure, Handi-Foam® SPF Roof Patch, Handi-Foam® Commercial Vehicle, Handi-Foam® Sound Barrier, Handi-Foam® Air Seal, Handi-Foam® Low Density, Hand-Foam® Slow Rise, Silent Seal® SA, and Handi-Foam® Black	LOW PRESSURE POLYURETHANE FOAM B-SIDE COMPONENT (134a); Handi-Foam® E84 Class 1, Handi-Foam® Quick Cure, Handi-Foam® SPF Roof Patch, Handi-Foam® Air Seal, Hand-Flow® Slow Rise, Handi-Foam® Black and Silent Seal® SA	HandiFoam Quick Cure
	Handi-Foam® Air Seal	LOW PRESSURE POLYURETHANE FOAM A-SIDE COMPONENT (134a); Handi-Foam® E84 Class 1, Handi-Foam® Quick Cure, Handi-Foam® SPF Roof Patch, Handi-Foam® Commercial Vehicle, Handi-Foam® Sound Barrier, Handi-Foam® Air Seal, Handi-Foam® Low Density, Hand-Foam® Slow Rise, Silent Seal® SA, and Handi-Foam® Black	LOW PRESSURE POLYURETHANE FOAM B-SIDE COMPONENT (134a); Handi-Foam® E84 Class 1, Handi-Foam® Quick Cure, Handi-Foam® SPF Roof Patch, Handi-Foam® Air Seal, Hand-Flow® Slow Rise, Handi-Foam® Black and Silent Seal® SA	HandiFoam Air Seal

Manufacturer Name	Product Name	Name on SDS		Name on PPN
		A-Side	B-Side	
ICP Adhesives & Sealants	Handi-Foam® Low Density	LOW PRESSURE POLYURETHANE FOAM A-SIDE COMPONENT (134a); Handi-Foam® E84 Class 1, Handi-Foam® Quick Cure, Handi-Foam® SPF Roof Patch, Handi-Foam® Commercial Vehicle, Handi-Foam® Sound Barrier, Handi-Foam® Air Seal, Handi-Foam® Low Density, Hand-Foam® Slow Rise, Silent Seal® SA, and Handi-Foam® Black	LOW PRESSURE POLYURETHANE FOAM B-SIDE COMPONENT LD (134a); Handi-Foam® Sound Barrier and Handi-Foam® Low Density	HandiFoam Low Density
	Handi-Foam® Wall Seal	LOW PRESSURE POLYURETHANE FOAM A-SIDE COMPONENT PIP WS WL (245fa); Handi-Foam® Wall Seal and Handi-Foam® Window Lineal	LOW PRESSURE POLYURETHANE FOAM B-SIDE COMPONENT PIP WS (245fa); Handi-Foam® Wall Seal	HandiFoam Wall Seal
	Brand A Product 1	CBI	CBI	CBI
	Brand B Product 1	CBI	CBI	CBI
	Brand B Product 2	CBI	CBI	CBI
	Brand B Product 3	CBI	CBI	CBI
Icynene-Lapolla	Icynene Classic Plus™	Base Seal (Component "A", Isocyanate)	LDC-70 Classic Plus™	Icynene Classic Plus
	Icynene Classic™	Base Seal (Component "A", Isocyanate)	LDC-50 - Classic™	Icynene Classic
	Icynene Classic Eco	Base Seal (Component "A", Isocyanate)	Classic Eco	Icynene Classic Eco
	Icynene Classic Max	Base Seal (Component "A", Isocyanate)	LDC-50-v2.4.2 TM – Classic Max - Select	Icynene Classic Max
	Icynene MDC 200 V6	Base Seal (Component "A", Isocyanate)	MDC200V6™	Icynene MDC 200
	Icynene MDR 210	Base Seal (Component "A", Isocyanate)	MDR-210TM - ProSeal Eco	Icynene MDR 210
	ProSeal Eco	Base Seal (Component "A", Isocyanate)	MDC200V3 - ProSeal	ProSeal Eco
	Icynene ProSeal	Base Seal (Component "A", Isocyanate)	MDC200V3 - ProSeal	Icynene ProSeal

Manufacturer Name	Product Name	Name on SDS		Name on PPN
		A-Side	B-Side	
Icynene-Lapolla	Lapolla Foam-LOK FL500	LaPolla Isocyanate	Foam-Lok FL 500	Lapolla Foam-LOK FL500
	Lapolla Foam-LOK FL2000	LaPolla Isocyanate	Foam-Lok FL 2000	Lapolla Foam-LOK FL2000
	Lapolla Foam-LOK FL2000 – 4G	LaPolla Isocyanate	Foam-Lok FL 2000-4G	Lapolla Foam-LOK FL2000 - 4G
	Lapolla Foam-LOK LPA 2500	LaPolla Isocyanate	Foam-Lok LPA 2500	Lapolla Foam-LOK LPA 2500
	Lapolla Foam-LOK LPA 2800	LaPolla Isocyanate	Foam-Lok LPA 2800	Lapolla Foam-LOK LPA2800
Johns Manville[3]	JM Corbond III® SPF	JM Spray Polyurethane Foam (SPF) – Component A (USA and Canada)	JM Closed-cell Spray Polyurethane Foam (cc SPF) – Component B (USA)	Corbond III® SPF
	JM Corbond® oc SPF	JM Spray Polyurethane Foam (SPF) – Component A (USA and Canada)	JM Open-cell (oc) and Open-cell Appendix x (ocx) Spray Polyurethane Foam (SPF) – Component B (USA)	Corbond® oc SPF
	JM Corbond® ocx SPF	JM Spray Polyurethane Foam (SPF) – Component A (USA and Canada)	JM Open-cell (oc) and Open-cell Appendix x (ocx) Spray Polyurethane Foam (SPF) – Component B (USA)	Corbond® ocx SPF
NCFI Polyurethanes[4]	10-011	A2-000	B-10-011	NCFI 10-011
	10-013	A2-000	B-10-013	NCFI 10-013
	11-016	A2-000	B-11-016 G&M series	NCFI 11-016
	11-017	A2-000	B-11-017 G&M series	NCFI 11-017
	11-033	A2-000	B-11-033	NCFI 11-033
	11-035	A2-000	B-11-035	NCFI 11-035
	11-036	A2-000	B-11-036	NCFI 11-036
	11-037	A2-000	B-11-037	NCFI 11-037
	12-008	A2-000	B-12-008	NCFI 12-008

Manufacturer Name	Product Name	Name on SDS		Name on PPN
		A-Side	B-Side	
Rhino Linings Corporation	ThermalGuard ISO, A Component	ThermalGuard ISO, A Component	N/A	ISO A-D
	Duratite CC2.5, B Component	ThermalGuard ISO, A Component	Duratite CC25, B Component	Duratite CC2.5
	Duratite CC2.8, B Component	ThermalGuard ISO, A Component	Duratite CC28, B Component	Duratite CC2.8
	Duratite CC3.0, B Component	ThermalGuard ISO, A Component	Duratite CC30, B Component	Duratite CC3.0
	ThermalGuard CC2, B Component	ThermalGuard ISO, A Component	ThermalGuard CC2, B Component	ThermalGuard CC2
	ThermalGuard OC 1.0, B Component	ThermalGuard ISO, A Component	ThermalGuard OC 1.0P, B Component	ThermalGuard OC 1.0
	ThermalGuard OC 0.5, B Component	ThermalGuard ISO, A Component	ThermalGuard OC 0.5P, B Component	ThermalGuard OC 0.5
SES Foam LLC	EasySeal.5 Spray Foam	Open Cell Spray Foam A-Component	EasySeal.5 Spray Foam B-Component	EasySeal.5 Spray Foam
	Nexseal™ 2.0, 2.0W, 2.0 LE, 2.0 LE W Spray Foam	Closed Cell Spray Foam A-Component	Nexseal™ 2.0, 2.0W, 2.0 LE, 2.0 LE W Spray Foam B-Component	Nexseal™ 2.0, 2.0W, 2.0 LE, 2.0 LE W Spray Foam
	SES 2.5, SES 2.5 S, SES 2.5 W Spray Foam	Closed Cell Spray Foam A-Component	SES 2.5, SES 2.5 S, SES 2.5 W	SES 2.5, SES 2.5 S, SES 2.5 W Spray Foam
	SES 2.7, SES 2.7 S, SES 2.7W Spray Foam	Closed Cell Spray Foam A-Component	SES 2.7, 2.7 S, 2.7 W Series Spray Foam B-Component	SES 2.7, SES 2.7 S, SES 2.7W Spray Foam
	SES 3.0, SES 3.0 S, SES 3.0W. SES 3.0HCS Spray Foam	Closed Cell Spray Foam A-Component	SES 3.0, 3.0 S, 3.0 W, 3.0 HCS Series Spray Foam B-Component	SES 3.0, SES 3.0 S, SES 3.0W. SES 3.0HCS Spray Foam
	Sucraseal™ 0.5 Spray Foam	Open Cell Spray Foam A-Component	Sucraseal™ 0.5 Spray Foam B-Component	Sucraseal™ 0.5 Spray Foam

Manufacturer Name	Product Name	Name on SDS		Name on PPN
		A-Side	B-Side	
SWD Urethane	Quik-Shield 100X	Quik-Shield A	Quik-Shield 100X B	Quik-Shield 100X
	Quik-Shield 106	Quik-Shield A	Quik-Shield 106 B	Quik-Shield 106
	Quik-Shield 108	Quik-Shield A	Quik-Shield 108 YM Resin (B)	Quik-Shield 108
	Quik-Shield 112	Quik-Shield A	Quik-Shield 112 B	Quik-Shield 112
	Quik-Shield 118	Quik-Shield A	Quik-Shield 118 Resin	Quik-Shield 118
	Quik-Shield 125	Quik-Shield A	Quik-Shield 125 B	Quik-Shield 125
	Quik-Shield 450	Quik-Shield A	Quik-Shield 450 B	Quik-Shield 450

Notes:
CalDTSC = California Department of Toxic Substances Control; CBI = Confidential Business Information; dba = Doing Business As; MDI = Methylene Diphenyl Diisocyanate; N/A = Not Applicable; PPN = Priority Product Notification; SDS = Safety Data Sheet; SPF = Spray Foam Polyurethane.
Sources: Product names and name on PPN were provided by the REs. SDSs can be found in Appendices A and A1 of this report.
(1) Accella Polyurethane Systems dba Acella Polyurethane Systems, Carlisle Spray Foam Insulation, Carlisle Roof Foam and Coatings.
(2) PREMISEAL 305 was replaced in May 2019 by PREMISEAL 70. PREMISEAL 350 was replaced in September 2019 by PREMISEAL 80.
(3) While Johns Manville chooses to include the names of the three Priority Products in the AA, the company maintains the CBI claim on all other information submitted to CalDTSC.
(4) Barnhardt Manufacturing Company dba NCFI® Polyurethanes.

3.4 Key Performance Requirements for the Priority Products

As noted above, the Priority Products all serve as insulation and an air, sound, and vapor barrier for residential and commercial buildings. Some products also function as moisture barriers. The key performance requirements for a two-component SPF are as follows:

- The product must be an effective barrier to heat (*i.e.*, the product must have thermal resistance and be an effective insulator). One reason that consumers may choose to use SPF products in a building is because of the high thermal resistance (R-value per inch) compared to other insulation products. The unique application process allows builders to create architectural designs that could not otherwise meet required energy performance standards using other insulation products.
- The product must be able to seal a wall assembly (where it is applied), serving as an effective barrier to air, vapor, moisture (closed-cell SPF), and sound.
- The product must resist the spreading of flames and emission of smoke in the case of a fire. Mandatory criteria for surface burning characteristics have been established by building codes to help ensure fire protection. For this reason, SPF products contain flame retardants.
- The product should have an appropriate reaction rate consistent with successful application of the product (in terms of seal, longevity, appearance, insulation capacity, *etc.*). For example, polyurethane-based spray foam polymerizes quickly, which:
    - Prevents slumping, thus providing a good seal for insulated cavities. Any alternatives would need to have equivalent performance properties in order to maintain the tight air barrier properties of SPF.
    - Reduces potential exposure to airborne pMDI. After application, the potential exposure is reduced to a level that allows other trades to enter the construction site in a timely manner.
    - Ensures that the product is fully reacted once it attains its final characteristics, which eliminates building occupants' exposure to pMDI.
- The product must have good dimensional stability (<15% change by volume). SPF products should resist structural deterioration/decomposition and resist settling, which maintains insulation performance over time.
- The product should also adhere directly to building materials (*e.g.*, wood, metal, plastic construction materials) and therefore improve structural integrity and stability.
- The product must be easy to spray, so that surfaces can be covered evenly and the product can get into gaps to properly form an air, sound, and/or moisture barrier.
- The product must maintain minimum standards for shelf life in order to provide consistent quality of the product and hence meet the required performance standards.

See Section 3.6 for information on the criteria for various physical characteristics of SPF products for different types and applications.

3.5 Information on SPF Product Grouping

Based on information provided by the REs listed in Table 3.1, there are over 170 different SPF products covered by this Abridged AA. Conducting an assessment of each product individually would be overly complicated and lead to difficulties in understanding comparisons of the various products. As a result, we have organized the Priority Products covered by this Abridged AA into four product groups based on their unique properties and applications (see Table 3.2). The grouping is divided among low- and high-pressure SPF products, further subdivided by product density (*e.g.*, 0.5 lb/ft^3). Further, this grouping is substantiated by the manner in which the SPF industry views these products – as four distinct product types.

The industry convention is to report a core density value (*i.e.*, 0.5, 2, or 3 lbs/ft^3) associated with different SPF products. This "weight value" is a bit of a misnomer but is used to indicate density (in lbs/ft^3 of cured SPF product). Higher weight indicates higher density, and higher-density products provide better insulation from air and vapor intrusion compared to lower-density products (US EPA, 2016). Low-pressure two-component SPF products, except high-volume low-pressure (HVLP) products, can be used by both professionals and do-it-yourself (DIY) applicators for weatherizing and small-scale insulation purposes (US EPA, 2016). HVLP SPF products are intended for use by professionals only and can be used for small-scale and full insulation jobs (*i.e.*, insulation of an entire structure). Only professionals can purchase and use high-pressure two-component SPF products (US EPA, 2016), which are for larger-scale insulation applications such as roofing, filling interior wall cavities, and continuous insulation (*i.e.*, continuous exterior insulation without gaps created by studs, joists, *etc.*) (SFC, 2020a). High-pressure SPF products fall into three groups: open-cell, 0.5-lb/ft^3 SPF used as wall cavity or attic insulation; closed-cell, 2-lb/ft^3 SPF also used for wall cavity insulation, attic insulation, and building exteriors; and closed-cell, 3-lb/ft^3 (or greater density) SPF used for building exteriors or roofs. While low-pressure SPF products are also available in various densities, we did not further divide the low-pressure SPF group. It should be noted that the division of products into groups is for clarity of discussion purposes only and reflects somewhat different uses; however, all the Priority Products are currently made with pMDI and similar B-side chemistries, at the same production facilities, and using the same storage tanks, blending equipment, and raw ingredients.

Product information that supports the use of these four product groups as Priority Products is provided in Appendix C.

Table 3.2 Grouping of Priority Products by Product Type

Group No.	Group Name	Applications
1	Low Pressure (various densities)	Typically used as air sealant and for small-scale insulation applications.
2	High Pressure, Open Cell, 0.5 lb/ft^3	Typically used as insulation for above grade interior wall cavities and unvented attics and crawlspaces.
3	High Pressure, Closed Cell, 2 lbs/ft^3	Typically used for exterior continuous insulation, insulation for above- and below-grade interior wall cavities, and insulation for unvented attics and crawlspaces. HVLP SPF products can be used for the insulation of full-size homes.
4	High Pressure, Closed Cell, 3 lbs/ft^3	Typically used in combination with elastomeric coatings as an insulated roofing system.

Notes:
HVLP = High Volume Low Pressure.
Source: SFC (2020a).

3.6 Legal Requirements, Standards, and Voluntary Programs Relevant to the Priority Products

The legal requirements relevant to the Priority Products are contained within the International Building Code (IBC), Residential Building Code (RBC), International Energy Conservation Code (IECC), and various federal, state, and local regulations.

As with many chemical-containing consumer products, low-pressure SPF that contains MDI is subject to the labeling requirements of the Federal Hazardous Substances Act (FHSA) and the California Hazardous Substances Act. FHSA requires that the ingredients of a product be specified and the hazards of those ingredients (*i.e.*, toxicity, flammability) be noted on product labeling if the ingredients meet certain threshold requirements (US CPSC, 2020). High-pressure SPF is regulated under the United States Occupational Safety and Health Administration (OSHA), the requirements of which are more extensive than the labeling requirements of the FHSA, because it is for professional use only. OSHA's requirements for the protection of worker health and safety, including that of professional SPF applicators, and for labeling products are discussed later in this section. Additionally, under the California Division of Occupational Safety and Health (CalOSHA), products containing MDI must list the substance on the occupational labels due to MDI's listing as a hazardous substance under California Code of Regulations (CCR) Title 8, Section 339 (CalOSHA, 2020).

MDI is currently listed as a federal hazardous air pollutant (HAP) under the Clean Air Act (CARB, 2020); however, there have been efforts to remove MDI from this list (US EPA, 2005). Due to MDI's federal HAP listing, MDI is automatically listed as a Toxic Air Contaminant (TAC) by the California Air Resources Board (CARB) (CARB, 2020) and is subject to the National Emission Standards for Hazardous Air Pollutants (NESHAPs). No maximum achievable control technologies (MACTs) have been identified for SPF. In addition, California air districts may establish and enforce relevant rules and regulations for volatile organic compounds (VOCs). For example, the South Coast Air Quality Management District (SCAQMD), which includes Los Angeles, has established a VOC limit of 250 g/L for foam insulation and foam sealant, which are considered architectural applications under Rule 1168 (SCAQMD, 2017). This limit is scheduled to be reduced to 50 g/L starting on January 1, 2023. This limit would also apply to any alternative SPF product. Furthermore, many SPF products have voluntary GREENGUARD Gold Certifications that comply with the California Department of Public Health (CDPH) Standard Practice for Specification version 1.2 (*i.e.*, California Specification 01350), indicating extremely low VOC emission (UL, 2020). Presumably, consumers would expect the same low VOC levels for any alternative SPF product.

MDI has multiple worker exposure limits, including a Permissible Exposure Limit (PEL) of 0.005 parts per million (ppm) under CalOSHA, a ceiling PEL of 0.02 ppm under US OSHA, a time-weighted average (TWA) Threshold Limit Value (TLV) of 0.005 ppm established by the American Conference of Governmental Industrial Hygienists (ACGIH), and a TWA Recommended Exposure Limit (REL) of 0.005 ppm set by the National Institute for Occupational Safety and Health (NIOSH) (UL LLC, 2020). Lastly, MDI has multiple additional RELs (12 $\mu g/m^3$ for acute exposure, 0.16 $\mu g/m^3$ for 8-hour exposure, and 0.08 $\mu g/m^3$ for chronic exposure) under the California Office of Environmental Health Hazard Assessment (CalOEHHA) (CalOEHHA, 2019a). It should be noted that neither MDI nor pMDI are listed under Proposition 65.

Building codes are developed by the International Code Council (ICC) as a minimum set of requirements to ensure the health and safety of building occupants (FEMA, 2020). The ICC codes are referred to as "model codes," as they are adopted by most states and enforced by local agencies, although some agencies may make adaptations or amendments to the model codes. The California Building Standards Code (Title 24 of the CCR) has 12 parts, including the California Building Code (CBC) and California Residential Code (CRC), which are based on the IBC and RBC, respectively (California Building Standards Commission, 2019a,b). The code chapters relevant to SPF insulation are Chapter 26 of the CBC and Chapter 3 of the CRC, and these chapters are distinct from those relating to non-SPF insulation. In general, the requirements and standards outlined in the codes focus on fire protection, thermal performance, and moisture control.

In addition to the CBC and the CRC, Title 24 includes the California Building Efficiency Standard (CBES) (CCR Title 24, Part 6) (California Building Standards Commission, 2019b). The CBES helps ensure that the most energy-efficient technologies and building practices are used for both newly constructed buildings and alterations and additions to existing buildings (California Energy Commission, 2018a). This standard outlines mandatory requirements for thermal insulation, including minimum R-values of total insulation for each climate zone. The CBES specifically references SPF insulation as a material that may be used to meet the specified requirements of an air barrier for building envelopes (California Energy Commission, 2018a). The standard also states that all insulation must be certified by the California Department of Consumer Affairs, Bureau of Household Goods and Services (formerly the Bureau of Electronic and Appliance Repair, Home Furnishing, and Thermal Insulation). As described in the Home Furnishings and Thermal Insulation Act, it is the responsibility of the Bureau of Household Goods and Services to provide licenses for insulation manufacturers and enforce the adopted regulations and standards (see Sections 19164, 19165) (California Dept. of Consumer Affairs, 2019). The Act also requires that insulation manufacturers develop and implement a quality assurance program and maintain a record of performance testing. These standards and enforcement procedures apply to all thermal insulating materials and would extend to any potential SPF alternatives (California Energy Commission, 2018a).

A set of specific criteria that help verify that SPF products conform to the complicated building code requirements for their intended use have been developed. All SPF products and potential alternatives must conform to the requirements laid out in the building standards. The ICC Evaluation Service (ICC-ES) developed "Acceptance Criteria for Spray-Applied Foam Plastic Insulation" (AC 377) to help interested parties such as building officials quickly evaluate the compliance of SPF products (ICC-ES, 2018). Similar compliance reports are issued by International Association of Plumbing and Mechanical Officials (IAPMO), Intertek, and others. These product-specific code compliance reports are developed based on the criteria outlined in AC 377 or equivalent criteria. The mandatory physical properties and standard test methods required by AC 377 for different SPF applications are presented in Table 3.3. Code compliance reports for SPF products outline these physical properties and confirm that the product is in compliance with the applicable building codes. In addition, these reports include sections on code compliance (*i.e.*, which version[s] of building codes the report adheres to), packaging and identification, thermal and ignition barrier requirements and special approvals, installation requirements, and quality assurance programs (ICC-ES, 2018). For specific products or systems based on particular end-uses, AC 377 indicates that alternative or additional quantification methods (*e.g.*, 3-year adhesion testing, transportation durability/road testing) may be submitted to and approved by ICC-ES prior to testing (ICC-ES, 2018). There are also several optional criteria and large-scale assembly tests outlined in AC 377, including air permeance to qualify as an air-impermeable insulation (American Society for Testing and Materials [ASTM] E2178 or E283), vapor permeance to qualify as a water vapor retarder (ASTM E96), and additional fire tests (*e.g.*, National Fire Protection Association [NFPA] Standards 285 and 286) (ICC-ES, 2018). Note that AC 377 does not provide minimum R-values for SPF. As a result, in California, the REs comply with the minimum R-values established in Appendix JA4 of the California Energy Commission Building Energy Efficiency Standards (California Energy Commission, 2018b). Many manufacturers also claim conformance to ASTM C1029, which includes compressive strength, water vapor permeability, water absorption, tensile strength, and closed cell content (Massaro, 2019). AC 377 also mentions ASTM C1029 as an alternative set of criteria and tests, specifically for insulation used in roofing (ICC-ES, 2018).

In addition to legal requirements, there are various retail-driven requirements (for low-pressure SPF only) and performance expectations for SPF products that would also apply to any alternatives. For example, application systems for low-pressure products should promote safety and ease of use (*e.g.*, preloading of blowing agent in sealed cylinders), and a 12-month shelf life is required by some REs' retail partners (Massaro, 2019). In addition, as noted earlier, some SPF products follow voluntary retail-driven product certification standards (*e.g.*, GREENGUARD).

During revision of this report, in response to comments from CalDTSC, IAPMO ES 1000 and ICC Standard 1100, which have similar criteria to AC 377, were published. However, the International Residential Code (IRC) still references AC 377.

Table 3.3 Physical Properties of Spray Polyurethane Foam (SPF) Insulation by Application According to AC 377

Application	Test Required	Value
Sealing (nominal core density 0.5-2.5 pcf)	Core Density: ASTM D1622	As reported
	Surface Burning Characteristics: IBC-ASTM E84 or UL 723	75 or lower flame-spread index, 450 or lower smoke-developed index
	Adhesion: ASTM D1623	5 lbf/in^2, minimum
Low-density insulation (nominal core density 0.5-1.4 pcf)	Thermal resistance at 75°F (24°C) Mean Temperature: ASTM C177, ASTM C518, or ASTM C1363	As reported
	Core Density:[1] ASTM D1622	As reported
	Tensile Strength: ASTM D1623	
	Minimum Closed Cell Content[2] of 90%	5 lbf/in^2, minimum
	Closed Cell Content Less than 90%	3 lbf/in^2, minimum
	Dimensional Stability: ASTM D2126	15% maximum total change
	Surface Burning Characteristics: IBC-ASTM E84 or UL 723	75 or lower flame-spread index, 450 or lower smoke-developed index
Medium-density insulation (nominal core density 1.5-3.5 pcf)	Thermal Resistance at 75°F (24°C) Mean Temperature: ASTM C177, ASTM C518, or ASTM C1363	As reported
	Core Density: ASTM D1622	As reported
	Tensile Strength: ASTM D1623	15 lbf/in^2, minimum
	Dimensional Stability: ASTM D2126	15% maximum total change
	Surface Burning Characteristics: IBC-ASTM E84 or UL 723	75 or lower flame-spread index, 450 or lower smoke-developed index
	Compressive Strength: ASTM D1621	15 lbf/in^2, minimum
Roofing (nominal core density 2.5-3.5 pcf)	Thermal Resistance at 75°F (24°C) Mean Temperature: ASTM C177, ASTM C518, or ASTM C1363	As reported
	Core Density: ASTM D1622	As reported
	Tensile Strength: ASTM D1623	40 lbf/in^2, minimum
	Dimensional Stability: ASTM D2126	15% maximum total change
	Surface Burning Characteristics: IBC-ASTM E84 or UL 723	75 or lower flame-spread index
	Compressive Strength: ASTM D1621	40 lbf/in^2, minimum

Notes:
ASTM = American Society for Testing and Materials; IBC = International Building Code; lbf = Pound Force; pcf = Pound Force Per Cubic Foot; UBC = Uniform Building Code; UL = Underwriters Laboratories Inc.
Table adapted from ICC-ES (2018, Table 1).
"For SI: 1 pfc = 16 02 kg/m^3, 1 lbf/in^2 = 6.89 kPa" (ICC-ES, 2018, Table 1).
(1) "Test specimen density shall be within 10 percent of the nominal density recognized in the evaluation report" (ICC-ES, 2018).
(2) "Closed cell content shall be determined in accordance with ASTM D6226" (ICC-ES, 2018).

Key Definitions:

- **Thermal Resistance (R-Value):** A measure of a material's resistance to conductive heat flow. The higher the thermal resistance (R-value), the greater the insulating power and the more effective the insulating material on a fixed-volume basis (US DOE, 2020a).
- **Surface Burning Characteristics:**
    - Flame-Spread Index: "A comparative measure, expressed as dimensionless number, derived from visual measurements of the spread of flame versus time for a material tested in accordance with ASTM E84 or UL 713" (ICC, 2015).
    - Smoke-Developed Index: "A comparative measure, expressed as dimensionless number, derived from smoke obscuration versus time for a material tested in accordance with ASTM E84" (ICC, 2015).
- **Core Density:** "Density is expressed most often in pounds per cubic foot… Core density… is the weight from the center of the sample" (Cutcher, 2016).
- **Tensile Strength:** "[T]ensile (pulling or stretching) force necessary to rupture a material sample divided by the sample's original cross sectional area. Units are usually kPa or psi or lb/in^2" (SPFA, 2020a).
- **Dimensional Stability:** "[T]he ability of a material to retain its original size and shape. For polyurethane foam, dimensional stability is determined over time under conditions of controlled temperature and humidity. Measured as a percent of original dimension" (SPFA, 2020a).
- **Compressive Strength:** "[T]he stress or force applied parallel to the direction of the polyurethane foam rise at 10% deformation or at yield point" (SPFA, 2020a).

According to the respiratory protection standards of OSHA (29 CFR 1910.134; OSHA, 2018) and CalOSHA (8 CCR 5144; CalOSHA, 2012), SPF applicators are required to wear appropriate personal protective equipment (PPE) when working with SPF products. In addition, OSHA's Hazard Communication Standard (HCS; 29 CFR 1910.1200) requires employers to provide warnings (*i.e.*, labels and SDS) and training to employees on chemical safety (OSHA, 2012). The Center for the Polyurethanes Industry (CPI) also offers an online training program for SPF applicators that involves basic information on chemical safety and the proper use of PPE (ACC, 2011). The Spray Polyurethane Foam Alliance (SPFA) has established a certification program for different types of SPF workers (*i.e.*, insulation installer, roofing insulation installer, and field examiner), with differing levels of proficiency (assistant, installer, master installer, and project manager), and requires progressive training in the proper use of SPF equipment, substrate preparation, equipment repair, codes and standards, *etc.* (SPFA, 2020b). It should be noted that these health and safety programs may require modification for any new alternative product.

California has also adopted several regulations that aim to reduce hydrofluorocarbon (HFC) emissions by prohibiting certain HFCs in specific product categories, including SPF insulation. The California Cooling Act (Senate Bill 1013; California State Senate, 2018) and CARB's HFC Regulation (CCR Title 17, Section 95372; CARB, 2018a) prohibit the use of certain HFC foam blowing agents in SPF products. The following HFC foam blowing agents are unacceptable if the formulation was blended after the effective date of January 1, 2020, for high-pressure rigid polyurethane two-component SPF, and as of January 1, 2021, for low-pressure rigid polyurethane two-component SPF: "HFC-134a, HFC-245fa, and blends thereof; blends of HFC-365mfc with at least 4 percent HFC-245fa, and commercial blends of HFC-365mfc with 7 to 13 percent HFC-227ea and the remainder HFC-365mfc; and Formacel TI" (CARB, 2018a). These HFCs may still be used in "military applications" until January 1, 2022, or "space- and aeronautics-related applications" until January 1, 2025 (CARB, 2018b). Any alternatives to high- or low-pressure SPF products would have to comply with California's HFC ban as well. Products containing the prohibited HFCs must be reformulated to work with alternative blowing agents (*e.g.*, hydrofluoroolefins [HFOs]) in order to continue to be manufactured and/or sold in California, which adds to the complexity of identifying safer alternatives.

3.7 Role of the Chemical of Concern in the Priority Products

The Priority Products are created from a chemical reaction between two components, the "A-side," which contains the unreacted MDI in the pMDI blend and, in low-pressure SPF systems, a blowing agent, and the "B-side," which contains a polyol, a flame retardant, a blowing agent, catalysts, and surfactants (CalDTSC, 2014). The two sides combine at a highly controlled ratio in the spray applicator system, creating polyurethane foam from the chemical reaction of the unreacted pMDI and the polyol with the help of the remaining B-side chemicals. Specifically, high-pressure SPF is polymerized upon release, whereas low-pressure SPF is not aerosolized and begins to polymerize prior to release from the spray gun. This polyurethane foam expands to fill building cavities and will completely cure into rigid foam (SFC, 2020a). An essential attribute of pMDI is its quick reaction time[3] with the polyol, which enables the foam to expand along a surface against the force of gravity, completely filling the space to be insulated rather than slumping to the lowest point of the application site.

3.8 Necessity of the Chemical of Concern or Replacement Chemicals in the Priority Products

As noted above, unreacted pMDI is a fundamental component of two-component SPF systems. A two-component SPF product formulated without unreacted pMDI or an equivalently effective replacement would not be functional. Thus, simply removing the chemical of concern from the Priority Products formulations without replacing it with a similarly reactive and effective ingredient is not an option.

[3] The SPF industry uses the terms "reaction time," "cure time," and "polymerization time" somewhat interchangeably. This report will use the term "reaction time" throughout, for consistency.

4 Scoping, Identifying Possible Alternatives, and Relevant Factors

4.1 Purpose and Approach for this AA

As conceived by Gradient and the RE consortium, the initial goal of an AA is to answer this question: Do seemingly functionally acceptable, technically feasible, and economically feasible alternatives to the Priority Products exist that should be given a more in-depth consideration (to determine if they qualify as safer alternatives), or can we be reasonably certain there are no such alternatives or that there is not sufficient publicly available information on potential alternatives to conduct an in-depth AA? It is the REs' position that an AA is based on publicly available information. In certain circumstances, the RE consortium requested that REs with additional knowledge of potential alternatives provide additional information to be included as part of the report or requested that the information be submitted to CalDTSC as CBI. The aim of the initial stage of an AA (*i.e.*, Stage 1) is not to definitively identify an alternative to the Priority Products, but rather to determine whether there are candidate alternatives with sufficient data regarding their hazards, exposure potential, performance, and cost to support more in-depth evaluation before a safer alternative is selected. If any safer alternative is found to exist, a Stage 2 AA is conducted; if they are found not to exist, then an Abridged AA is submitted (which, as noted in Section 6, is the outcome here). We believe this approach is consistent with the California SCP regulations (CalDTSC, 2013). Other important elements of an AA include identifying requirements (legal or otherwise) for the product and identifying the function of the chemical of concern in the product to determine whether the chemical can simply be eliminated from the product.

4.2 Scoping: Alternatives Outside the Scope of this Abridged AA Report

The first element of an AA involves scoping, or determining, the range of alternatives to the Priority Product(s) that will and will not be considered in the AA. "Alternative" has a narrow definition in the context of the SCP regulations and are defined under 22 CCR § 69501.1 as consisting of the following options:

> A. Removal of Chemical(s) of Concern from a Priority Product, with or without the use of one or more replacement chemicals;
> B. Reformulation or redesign of a Priority Product and/or manufacturing process to eliminate or reduce the concentration of Chemical(s) of Concern in the Priority Product;
> C. Redesign of a Priority Product and/or manufacturing process to reduce or restrict potential exposures to Chemical(s) of Concern in the Priority Product; or
> D. Any other change to a Priority Product or a manufacturing process that reduces the potential adverse impacts and/or potential exposures associated with the Chemical(s) of Concern in the Priority Product, and/or the potential adverse waste and end-of-life effects associated with the Priority Product. (CalDTSC, 2013)

SPF is a multifunctional product, *i.e.*, open- and closed-cell, which typically share similar storage, manufacturing, and dispensing equipment. As a result, it is the REs' position that any safer alternative, as defined by the SCP regulations, would need to replace all of the existing functions of the Priority Products (*i.e.*, low-pressure SPF and high-pressure 0.5-, 2.0-, and 3-lb SPF) in a single product type. Having an alternative for only certain types of Priority Product could adversely complicate product production, requiring additional production facilities (*i.e.*, more land use) and greater raw material transportation. It could also complicate worker training, as all SPF workers currently only need to receive training regarding the proper use of a single type of material. See Section 6.3 for more information.

4.2.1 Other Insulation Products that Are Out of Scope

This Abridged AA is focused on alternatives to two-component low- and high-pressure SPF products containing unreacted MDI. While other types of insulation, such as fiberglass, mineral wool, cellulose, natural fibers, polystyrene, and cementitious foam, would provide only some of the same functions as the Priority Products, the REs do not consider these as "alternatives" as defined by 22 CCR § 69501.1 (CalDTSC, 2013) and 22 CCR § 69511.2 (CalDTSC, 2018). First, these other types of insulation are not based on a reformulation, redesign, or change to the existing Priority Products but rather are wholly different products. None of these products replicate the multiple functional benefits of SPF (air barrier, moisture barrier, vapor retarder, thermal and acoustic barrier, and added structural strength) without secondary products. For example, additional insulation thickness is required for these other types of insulation materials to achieve the equivalent R-values that SPF can provide. Second, the REs believe these other types of insulation are outside the scope of the AA because they do not meet the definition of the Priority Products, as they are not a spray-applied foam. In addition, CalDTSC's "Alternatives Analysis Guide" (CalDTSC, 2017a) indicates that REs are not required to consider alternatives that fall outside their business manufacturing model (CalDTSC, 2017a, p. 26). The SCP regulations also encourage CalDTSC to consider the "practical capacity" of an RE to carry out a regulatory action that CalDTSC may require, such as mandating that an alternative technology be used (CalDTSC, 2013). The systems houses that have participated in the preparation and submission of this Abridged AA report view non-spray-foam-based insulation technologies as being outside many of their manufacturing business models and as technologies that they have no practical capacity to produce. These technologies are therefore considered to be outside the scope of this AA and cannot be considered alternatives to the Priority Products.

However, in the interest of completeness and transparency, a qualitative discussion of these non-SPF alternatives and why they are not suitable replacements for pressurized two-component SPF systems containing unreacted MDI is provided below.

4.2.1.1 Fiberglass

Fiberglass is an insulation material consisting of fine glass fibers. Fiberglass insulation products are not an alternative to SPF. Fiberglass products are typically used only in interior applications, while SPF can be used in both interior and exterior applications. Fiberglass insulation products are air permeable and cannot function as an air barrier or sealant (Holladay, 2009) without the use of additional products. Fiberglass insulation products by themselves cannot function as a water-resistive barrier. Fiberglass insulation cannot strengthen the structure of a building. Finally, fiberglass insulation products represent a completely different product chemistry (and application) from SPF and do not meet the SCP regulations' definition of an alternative. They also clearly fall outside the manufacturing or business model of REs that do not manufacture fiberglass insulation and are thus outside the scope of this AA.

4.2.1.2 Mineral Wool

Rock wool, rock and slag wool, and slag wool are insulation fibers made up of different proportions of blast furnace slag, aluminosilicate rock (*e.g.*, basalt), and other rocks (US DOE, 2020b). Mineral wool insulation products are not an alternative to SPF. Mineral wool insulation products are air permeable and cannot function as an air barrier or sealant without the use of additional products. Mineral wool insulation products by themselves cannot function as a water-resistive barrier. Mineral wool insulation cannot strengthen the structure of a building. Finally, mineral wool insulation products represent a completely different product chemistry (and application) from SPF and do not meet the SCP regulations' definition of an alternative. They also clearly fall outside the manufacturing or business model of REs that do not manufacture mineral wool insulation and are thus outside the scope of this AA.

4.2.1.3 Cellulose

Cellulose insulation typically consists of recycled paper, borate, and ammonium sulfate (US DOE, 2020b). Cellulose insulation products are not an alternative to SPF. Cellulose insulation products are only used in interior applications, while SPF can be used in both interior and exterior applications. Cellulose insulation products are air permeable and cannot function as an air barrier or sealant without the use of additional products. Cellulose insulation products by themselves cannot function as a water-resistive barrier. In fact, cellulose insulation products are susceptible to water damage. Cellulose insulation cannot strengthen the structure of a building. Finally, cellulose insulation products represent a completely different product chemistry (and application) from SPF and do not meet the SCP regulations' definition of an alternative. They also clearly fall outside the manufacturing or business model of REs that do not manufacture cellulose insulation and are thus outside the scope of this AA.

4.2.1.4 Natural Fiber

Natural fiber insulations include cotton, sheep's wool, *etc.* (US DOE, 2020b). Natural fiber insulation products are not an alternative to SPF. Natural fiber insulation products are only used in interior applications, while SPF can be used in both interior and exterior applications. Natural fiber insulation products are air permeable and cannot function as an air barrier or sealant without the use of additional products. Natural fiber insulation products by themselves cannot function as a water-resistive barrier. Like cellulose insulation products, natural fiber insulation products are susceptible to water damage. Natural fiber insulation cannot strengthen the structure of a building. Finally, natural fiber insulation products represent a completely different product chemistry (and application) from SPF and do not meet the SCP regulations' definition of an alternative. They also clearly fall outside the manufacturing or business model of REs that do not manufacture natural fiber insulation and are thus outside the scope of this AA.

4.2.1.5 Polystyrene

Polystyrene is a thermoplastic insulation that comes in various forms, such as extruded or expanded foam boards, concrete blocks, and compressed bead boards (US DOE, 2020b). Polystyrene insulation products are not an alternative to SPF. While polystyrene materials are air impearmable, additional products are required for polystyrene wall assemblies to meet air barrier performance requirements. Polystryrene insulation products cannot seal cracks and gaps. Polystyrene insulation cannot strengthen the structure of a building. Additionally, polystyrene insulation products represent a completely different product chemistry (and application) from SPF and do not meet the SCP regulations' definition of an alternative.

They also clearly fall outside the manufacturing or business model of REs that do not manufacture polystyrene and are outside the scope of this AA.

4.2.1.6 Cementitious Foam

As the name suggests, cementitious foam is a cement-based foam either installed as spray-applied or foam-in-place insulation (US DOE, 2020b). Cementitious foam insulation products are not an alternative to SPF. Cementitious foam insulation products are fragile and crumble (Roberts, 2014); therefore, they are air permeable and cannot function as an air barrier or sealant without the use of additional products. Cementitious foam insulation products by themselves cannot function as a water-resistive barrier. Cementitious foam insulation cannot strengthen the structure of building. Finally, cementitious foam insulation products represent a completely different product chemistry (and application) from SPF and do not meet the SCP regulations' definition of an alternative. They also clearly fall outside the manufacturing or business model of REs that do not manufacture cementitious foam insulation and are thus outside the scope of this AA.

4.2.1.7 Polyisocyanurate

Polyisocyanurate or polyiso is a thermoset plastic, closed-cell foam similar to polyurethane insulation (US DOE, 2020b). Polyisocyanurate rigid board insulation products are not an alternative to SPF. Like polyurethane, polyisocyanurate is created *via* a thermochemical reaction between MDI and polyols and catalysts, surfactants, and flame retardants (PIMA, 2015). However, this process occurs at a manufacturing site using a vastly different process, typically including the use of metal or plastic facers, which require specialized lamination equipment. Polyisocyanurate insulation products are not spray applied. While polyisocyanurate materials are air impermeable, additional products are required for polyisocyanurate wall assemblies to meet air barrier performance requirements. Polyisocyanurate insulation products cannot seal cracks and gaps. They also clearly fall outside the manufacturing or business model of REs that do not manufacture polyisocyanurate and are thus outside the scope of this AA.

4.3 Potential Alternatives

Once the scope of an AA has been identified, the next critical step is to gather information on possible alternatives to the Priority Product(s). To conduct an informative AA, one needs to consider not only those products made by the REs involved in this particular effort but also other similar products that are available, as these may be possible alternatives to the Priority Product(s). To obtain information about potential alternatives to the Priority Products, we first gathered information from SDSs for all the products made by the REs involved in this Abridged AA. We then researched potential alternatives mentioned in CalDTSC's "Revised Priority Product Profile" for SPF products containing unreacted MDI (CalDTSC, 2014).[4]

We also conducted an online literature search using terms such as "spray foam insulation," "alternatives," "insulation types," "insulation options," *etc*. In addition, we consulted several recent textbooks on insulation and reviewed CalDTSC's technical document related to the listing of SPF containing unreacted

[4] Soudal's Soudafoam SMX® is a one-component, non-isocyanate-based canned spray foam that was mentioned in the CalDTSC "Revised Priority Product Profile" for SPF products containing unreacted MDI as a potential commercially available alternative to these products (CalDTSC, 2014). However, because Soudafoam SMX® is a one-component spray foam only available in 500-mL cans (Soudal Australia, 2020), it is not a viable potential alternative for two-component Priority Products and thus is not included in this Abridged AA. In addition, it is unclear whether Soudafoam SMX® is currently commercially available in the US, because the product is not available on Soudal's US website (Soudal Inc., 2020), but is available on its Australian website (Soudal Australia, 2020).

MDI as a Priority Product (CalDTSC, 2017b). Additionally, we conducted two patent searches relating to pMDI/MDI-based SPF using Google Patents, the United States Patents and Trademarks Office patent search database, and the patent search functionality on LENS.org. For these patent searches, search terms for SPF (sprayfoam, spray foam) were used with MDI/methylene diphenyl diisocyanate and insulation/insulated to form the first part of the search. For the patent search focusing on alternative chemistries to MDI-based SPF, keywords including alternative chemistry, green chemistry, non-hazardous, less toxic, and safe/safer were used in conjunction with the previously mentioned keywords for SPF. For patents focusing on SPF approaches that lower exposure to pMDI/MDI, keywords including reduced exposure, lower exposure, limited exposure, or less exposure were used in conjunction with the previously mentioned keywords for SPF. Both of these searches yielded few results in all three patent databases and are presented below.

We also asked members of the RE consortium to provide information on any alternative technologies to the Priority Products that they are aware of that currently exist, are under development, or have been tried in the past.

Note that we limited our search to current alternatives to pMDI/MDI-based *spray polyurethane foams* and not to alternatives to pMDI/MDI-based *polyurethanes* in general.[5] Polyurethanes are used in a very wide range of products (*e.g.*, coatings, textiles, foam) with very different product characteristics, and alternative chemistries for such applications would not provide useful information about their potential use as spray foam building insulation. Only technologies that are alternatives specific to pMDI/MDI-based spray foam building insulation were considered.[6]

4.3.1 Non-MDI-based Alternative Formulations

Through the various approaches outlined above, a number of potential non-MDI-based alternative formulations for the Priority Products were identified that appear to replicate some of the current Priority Products' functional abilities (*e.g.*, sprayable, two-component). These formulations are:

1. Firestone/Gaco Canary™;
2. NanoSonic HybridSil™;
3. Hybrid Coatings Technologies/Nanotech Industries Green Polyurethane™;
4. Owens Corning Formulation;
5. DuPont Formulations (two); and
6. Dow Formulation.

4.3.1.1 Firestone/Gaco Canary™

In 2016, Gaco Western patented a two-component, closed-cell, 2.5-lb/ft^3, non-polyurethane, non-isocyanate-based spray foam formulation that uses the same application equipment and has the same PPE requirements as the current Priority Products, called Canary™ (Gaco Western, 2017a; Trumbo, *et al*.,

[5] For example, the Danish Ministry of the Environment studied alternatives to MDI in coatings, adhesives, and sealants but did not address spray foam insulation in that assessment (Danish EPA, 2015).

[6] For example, we found one product (Bautex) that involves making non-MDI-based insulating cement blocks for commercial building construction. Such a product, if adopted as an SPF replacement, would mandate a complete change in construction technology (*e.g.*, from wood or other materials to concrete), which would be outside the scope of the SCP regulations.

2016). General information on example chemicals (or chemical families) to be used in the formulation are contained in the patent for this product (Patent No. US 9359471 B2 [Trumbo, *et al*., 2016]), although it is not certain these would be the same chemicals as those used in a marketed version of the product. An example formulation for Canary contains the following compounds.[7]

Example Formulation:

- Acetoacetylated Sucrose (no CAS No. identified)
- Acetoacetylated Glycerin (no CAS No. identified)
- Meta Xylene Diamine (MXDA) (CAS No. 1477-55-0)
- Dytek® A (2-Methyl-1,5-diaminopentane) (CAS No. 15520-10-2)
- Tin Catalyst (Dimethylbis[(1-oxoneodecyl)oxy]stannane) (CAS No. 68928-76-7)
- Tegostab™ B-8407, a polyether modified siloxane surfactant (CAS No 67762-85-0)
- Tegostab™ B-8221, a silicone surfactant (no CAS No. identified)
- tris(2-Chloropropylphosphate) (TCPP), a flame retardant (CAS No. 1067-98-7)
- HFC-365mfc, an HFC blowing agent (CAS No. 406-58-6)

See Section 5 for more information on product-level performance (if any) and ingredient-level hazards and exposure potential.

4.3.1.2 NanoSonic HybridSil™

HybridSil™ is a two-component, closed-cell, non-isocyanate, silicon-based spray foam insulation that was, in part, funded by the United States Environmental Protection Agency (US EPA) Small Business Innovation Research Program in an effort to develop an alternative to SPF (NanoSonic Inc., 2012, 2013). According to NanoSonic, HybridSil is air-tight and the same traditional SPF equipment can be used for applying it (NanoSonic Inc., 2012). As of October 8, 2020, NanoSonic does not appear to have a patent for HybridSil. The product is not listed on NanoSonic's website.

4.3.1.3 Hybrid Coatings Technologies/Nanotech Industries Green Polyurethane™

A press release from 2014 stated that Hybrid Coatings Technologies had acquired a "hybrid non-isocyanate polyurethane (HNIPU)" spray foam technology from a organization called Nanotech Industries, Inc. (Hybrid Coating Technologies Inc., 2014). The press release gave the name of the product as Green Polyurethane™ and claimed that this formulation has performance characteristics similar to those of an MDI-based spray foam, although no specifics on the chemical components of the formulation were identified in the press release. In 2015, a US patent (Figovsky *et al*., 2015) granted to Nanotech Industries, Inc. (Patent No. US 2015/0024138 A1) for this product indicates that the patented formulation has the following composition.[8]

[7] Trade names are given in the patent, but not CAS Nos. Gradient attempted to identify CAS Nos. for the various ingredients, but was unable to assign CAS Nos. for some ingredients.
[8] Trade names are given in the patent, but not CAS Nos. Gradient attempted to identify CAS Nos. for the various ingredients, but was unable to assign CAS Nos. for a few ingredients.

Example Formulation:

- DER 331, a bisphenol A (BPA) epoxy resin (CAS No. 25085-99-8)
- Ancamine 2678, an aliphatic amine curing agent (no CAS No. identified)
- DC-1107 Fluid, a silicone surfactant (CAS Nos. 63148-57-2, 68037-53-6, and 142-82-5)
- DC-197, a silicone surfactant (undisclosed CAS No. and CAS No. 34590-94-8)
- Undisclosed blowing agent

According to the patent, other potential ingredients include acrylates or carbonates instead of the epoxy, which could potentially contain renewable sources such as acrylated epoxidized soybean oil or carbonized soybean oil. The patent also implies that a blowing agent (*e.g.*, an HFC) was used, but the identity of the blowing agent is not provided. The formulation contains a California Candidate Chemical, n-heptane (CAS No. 142-82-5) (CalDTSC, 2019a). In addition, BPA resin (CAS No. 25085-99-8) is made with BPA (CAS No. 80-05-7), which is another California Candidate Chemical (CalDTSC, 2019a). As of October 8, 2020, the Hybrid Coatings Technologies website no longer exists. However, Green Polyurethane was found as a commercial product on Nanotech Industries's website, for applications of coatings, composites, and compounds to foam and adhesives (Nanotech Industries, Inc., 2020). Nanotech Industries's website gives no indication that the material presented in the patent (Figovsky *et al.*, 2015) for wall and roofing purposes has moved towards the commercialization stage. No SDS relating to this patent was located. See Section 5 for more information on product-level performance (if any) and ingredient-level hazards and exposure potential.

4.3.1.4 Owens Corning Formulation

In 2012, Owens Corning was granted a patent (No. US 2012/0183694 A1) for an open- and closed-cell, non-isocyanate-based "polyurethane" spray foam "made by reacting cyclo carbonates and di- or polyamines" (Olang, 2012). The patent further states that the formulation contains optional acrylate monomers or epoxy or acrylic resins, as well as rheology modifiers (which modify material flow) and blowing agents. The patent notes that non-isocyanate-based urethanes typically have slow reactivity (which is an issue because the foam needs to quickly form to support itself along the surface it has been applied to, rather than slumping downwards), and in this formulation, the reactive acrylates are included to add additional heat to speed the reaction. The temperature range of the applied foam ranges from 120 to 150°F, which is greater than that typical for the Priority Products (*i.e.*, 125 to 130°F). Several formulations are specified in the Owens Corning patent (Olang, 2012). The base formulation contains the following compounds.[9]

Example Formulation:

- DER 331, a BPA epoxy resin (CAS No. 25085-99-8)
- Epon™ 8111, a multifunctional epoxy resin (CAS Nos. 25068-38-6 and 15625-89-5)
- Cycloate A, an aliphatic amine (CAS No. 1134-23-2)/Ancamine 2678, an aliphatic amine curing agent (no CAS No. identified)
- Sodium Hydroxide (CAS No. 1310-73-2)

[9] Trade names are given in the patent, but not CAS Nos. Gradient attempted to identify CAS Nos. for the various ingredients, but was unable to assign CAS Nos. for a few ingredients.

- Epikure™ 3271, an amine curing agent (CAS Nos. 111-40-0 and 80-05-7)
- DC193, a polysiloxane surfactant (no CAS No. identified)
- Dye (specific name not stated and no CAS No. identified)
- Undisclosed blowing agent
- Undisclosed flame retardant

As with the Green Polyurethane patent, the patent for the Owens Corning formulation implies that a blowing agent (*e.g.*, an HFC) and flame retardant were used, but the identities of these are not provided. Modifications described in the patent include the addition of a clay-based flow modifier (Garamite-1958) or the use of a different blowing agent (*i.e.*, hexafluorobutene). As with the Firestone/Gaco Canary formulation, the information contained in the patent does not provide specific chemicals that would be used in a marketed version of the formulation, creating uncertainty regarding the accuracy of the AA for this material. No SDS relating to this patent was located. However, two chemicals in the example formulation provided in the patent are on the California Candidate Chemicals list (*i.e.*, trimethylolpropane triacrylate, CAS No. 15625-89-5, and sodium hydroxide, CAS No. 1310-73-2) (CalDTSC, 2019a). In addition, BPA resin (CAS No. 25085-99-8) is made with BPA (CAS No. 80-05-7), which is another California Candidate Chemical (CalDTSC, 2019a). Furthermore, an article discussing this formulation (Figovsky *et al.*, 2013) suggests that viscosity issues are significant challenges for using this technology in a sprayable product. See Section 5 for more information on product-level performance (if any) and ingredient-level hazards and exposure potential.

4.3.1.5 DuPont Formulations

DuPont has two patents for non-isocyanate-based spray foam, one granted in 2013 (Patent No. WO 2013/101682 A1) and another granted in 2018 (Patent No. WO 2018/005142 A1) (Jin *et al.*, 2013; Thomas *et al.*, 2018).

Patent No. WO 2013/101682 A1

The 2013 DuPont patent (No. WO 2013/101682 A1) describes an alternative spray foam product produced *via* carbon-Michael chemistry rather than the polyurethane chemistry (Jin *et al.*, 2013). A total of 15 potential formulations are listed in this patent, indicating a high degree of uncertainty regarding what the final formulation would be. One of the flame retardants listed in the example formulation below is a California Candidate Chemical (*i.e.*, TCPP, CAS No. 13674-84-5) (CalDTSC, 2019a). In addition, difunctional acrylate A, a BPA epoxy diacrylate (CAS No. 55818-57-0) is made with BPA (CAS No. 80-05-7), which is another California Candidate Chemical (CalDTSC, 2019a). This patent does include the following performance information for some, but not all, of the example formulations: compressive strength according to ASTM D1621-10, open cell content according to ASTM D6226-10, density according to ASTM D-1622-03, and flame-spread index and smoke-development index according to ASTM E84 and E84-12, respectively. However, no information was available on any of the formulations' tensile strength, dimensional stability, or thermal resistance. This patent formulation also includes the use of blowing agents (HFC-245fa and -134a), which were banned in California in 2020 for high-pressure SPF products and alternatives, and will be banned in 2021 for low-pressure SPF products and alternatives (CARB, 2018a). An example of a potential formulation is shown below.[10]

[10] Trade names are given in the patent, but not CAS Nos. Gradient attempted to identify CAS Nos. for the various ingredients, but was unable to assign CAS Nos. for one ingredient.

Example Formulation:

- Tetrafunctional Acrylate (CAS No. 94108-97-1)
- Difunctional Acrylate A, a BPA epoxy diacrylate (CAS No. 55818-57-0)
- Trimethylolpropane tris(Acetoacetonate) (CAS No. 22208-25-9)
- Tegostab™ B8469, a surfactant (no CAS No. identified)
- HFC-245fa, a blowing agent (CAS No. 460-73-1)
- HFC-134a, a blowing agent (CAS No. 811-97-2)
- N,N,N',N'-Tetramethylguanidine (TMG) (CAS No. 80-70-6)
- Tri(2-chloropropyl)phosphate (TCPP), a flame retardant (CAS No. 13674-84-5)
- Triethyl Phosphate (TEP) (CAS No. 78-40-0)

Patent No. WO 2018/005142 A1

The 2018 DuPont patent (No. WO 2018/005142 A1) (Thomas *et al*., 2018) describes an improved and hydrolytically stable biodegradation polyol-based "isocyanate-free polyurethane foam," compared to the 2015 Dow patent (Patent No. WO 2015/142564 A1; Foley *et al*., 2015) discussed in Section 4.3.6. The A-side MDI equivalent in this formulation is stated to be a polycarbamate, similar to the 2015 Dow patent. Alkali metal oxides (magnesium oxide, magnesium hydroxide, calcium oxide) are added to increase resistance to hydrolysis. The patent mentions a wide range of classes of possible acid catalysts and several possible HFC blowing agents that could be used in the final formulation. The patent also indicates that a flame retardant, "such as any of those used in polyurethane," can be used in the product formulation (Thomas *et al*., 2018). No performance data are provided in the patent. While the patent seems to be focused on methods for producing the foam and ingredients, no clear formulations were given. An example of a potential formulation is shown below.[11]

Example Formulation:

- Polycarbamate 2 (DuPont has not applied for a CAS No. for this ingredient)
- 1,3- and 1,4-Cyclohexanedicarboxaldehyde (CHDA) (EC No. 482-020-3, no CAS No.)
- Tetrabromophthalate Diol (TBPD), a flame retardant (CAS No. 77098-07-8)
- Triethyl Phosphate (TEP) (CAS No. 78-40-0)
- Silicone Polyether Copolymer Surfactant (no CAS No. identified)
- P-Toluenesulfonic Acid, a catalyst (CAS No. 6192-52-5)
- Magnesium Oxide (CAS No. 1309-48-4)
- HFC-245fa, a blowing agent (CAS No. 460-73-1)

As with all of the previous patent formulations, the two DuPont patents reference hundreds of possible ingredient combinations that could be used in the final marketed versions of the formulations, rather than providing specific chemicals that would be used in them, creating uncertainty regarding the accuracy of the

[11] Trade names are given in the patent, but not CAS Nos. Gradient attempted to identify CAS Nos. for the various ingredients, but was unable to assign CAS Nos. for a few ingredients.

AA for these formulations. DuPont confirmed that no SDS is available for either patent. See Section 5 for more information on product-level performance (if any) and ingredient-level hazards and exposure potential.

4.3.1.6 Dow Formulation

In 2015, Dow was granted a patent (Patent No. WO 2015/142564 A1) for a non-isocyanate-based, biodegradable, and water-soluble polyol-based foam (Foley *et al*., 2015). This foam is subject to hydrolysis and can lose up to 24% weight in tests. A water-soluble alternative formulation is problematic, because current SPFs provide moisture resistance and structural support, and any safer alternative would need to provide similar functionality. The A-side MDI equivalent in this formulation is stated to be a polycarbamate. The patent describes multiple potential A- and B-side ingredients for the formulation. Information on density, compressive strength, and open cell content is provided for one potential formulation, but not others. An example of a potential formulation is shown below.[12]

Example Formulation:

- Polycarbamate (no CAS No. identified)
- 1,3- and 1,4-Cyclohexanedicarboxaldehyde (CHDA) (EC No. 482-020-3, no CAS No.)
- Triethyl Phosphate (TEP) (CAS No. 78-40-0)
- Niax L5340, a silicone surfactant (no CAS No. identified)
- Tetrabromophthalate Diol (TBPD), a flame retardant (CAS No. 77098-07-8)
- Undisclosed catalyst ("Lewis acids" or "protic acids")

As with all of the previous patent formulations, the Dow patent describes multiple example formulations and does not provide specific chemicals that would be used in a marketed version of the formulation, thus creating uncertainty regarding the accuracy of the AA for this formulation. Dow confirmed that no SDS is available for this patent and the product is not commercially available. See Section 5 for more information on product-level performance (if any) and ingredient-level hazards and exposure potential.

SPF and any alternative must meet the requirements laid out in various state and local regulations and building standards outlined in AC 377 (ICC-ES, 2018). The performance criteria outlined in AC 377 include thermal resistance (ASTM C177, ASTM C518, or ASTM C1363), core density (ASTM D1622), tensile strength (ASTM D1623), dimensional stability (ASTM D2126), surface burning characteristics (IBC-ASTM E84 or UL 723), and compressive strength (ASTM D1621). Limited data on the formulation's performance (*e.g.*, core density and compressive strength) are discussed in this patent; other critical product information is missing (*e.g.*, anticipated density, R-value, tensile strength, and flame-spread resistance).

[12] Trade names are given in the patent, but not CAS Nos. Gradient attempted to identify CAS Nos. for the various ingredients, but was unable to assign CAS Nos. for a few ingredients.

4.3.2 Lower-Exposure Approaches

Through the various searches outlined in Section 4.3, a number of potential approaches that might lower exposure to MDI compared to the Priority Products were identified. These approaches still use unreacted MDI and are Priority Products. They include:

1. Firestone/Gaco Profill System™;
2. HVLP; and
3. BASF patents (two).

As discussed in Section 6.1, the REs maintain that these products or potential approaches are themselves Priority Products and, given the lack of an Alternatives Analysis Threshold (AAT), cannot be considered safer alternatives under the SCP regulations. Additionally, CalDTSC has previously rejected engineering controls to reduce exposure to MDI during SPF application as an alternative solution to the AA process for the Priority Products (Lee, 2015).

4.3.2.1 Firestone/Gaco Profill System™

Firestone/Gaco has a Priority Product, Profill System™, that reduces applicators' exposure to unreacted MDI by installing the spray foam behind plastic membranes or aluminum channels (Gaco Western, 2020); however, use of the system still requires full PPE due to the possibility of mishaps (*e.g.*, overspray, bursting of membranes). Profill System encompasses three different products, GacoProWeb, GacoProFilm, and GacoProCap System, that use open-mesh polypropylene membrane, continuous fiber-reinforced polyethylene film, and removable aluminum channels, respectively (Gaco Western, 2020). Compared to traditional SPF, less trimming is required for Profill System products, because workers are injecting SPF behind a membrane, film, or aluminum channels. However, trimming would be necessary when user error occurs. In addition, additional preparation time is required to install the membranes or channels prior to SPF application. The Profill System formulation also contains several California Candidate Chemicals, including MDI (CAS No. 101-68-8), pMDI (CAS No. 9016-87-9), and ethoxylated nonylphenols (CAS No. 127087-87-0) (CalDTSC, 2019a; Gaco Western, 2017b). It should be noted that the formulation used in Profill System was specially formulated so that the foam does not rupture the membranes, which would occur with traditional SPF formulations.

Workers that use Profill System must wear PPE, such as a NIOSH-approved full face or hood supplied-air respirator, MDI-resistant gloves and booties, and chemically resistant full-body suits with a hood (Gaco, c. 2020). Under OSHA, SPF contractors are legally required to provide safe work conditions for all employees (ACC, 2016a). Guidelines and training for indoor application of high-pressure SPF include several steps to help ensure worker safety, including engineering controls, such as workplace containment and ventilation design, followed by appropriate work practice (*e.g.*, site preparation, appropriate chemical storage and handling, communications with occupants and other workers), and lastly, appropriate PPE (ACC, 2016b). For ventilation, SPF applicators should assess the space and implement work zone mechanical ventilation during and after SPF application, such as by using a combination of both supplied air and active exhaust ventilation systems. A supplied air system pumps in fresh air, while an active exhaust system creates a slight negative pressure *via* exhaust fans to funnel air flow (*i.e.*, unwanted chemicals) from the work zone to a designated location outside the building and away from occupants and workers (ACC, 2016a).

Under appropriate ventilation and measured at least 30 minutes after SPF application, MDI cannot be detected when applying standard low-density high-pressure SPF (Table 5.11; Wood, 2017). MDI was detected when measured during SPF application with ventilation (0.0153 ppm) at the applicator's location and (0.0077 ppm) 2 ft behind the applicator. Unfortunately, no comparable data exist for Profill System *with* ventilation. Comparative exposure data are available for application *without* ventilation (*i.e.*, closed windows and no fans, an atypical situation). In a single study with no ventilation, which is not recommended for the application of traditional SPF or Profill System, exposure to MDI was lower with Firestone/Gaco ProFilm and ProWeb products compared to standard low-density high-pressure SPF (Table 5.11; Nelson, 2015; Wood, 2017).

See Section 5 for more information on product-level emission, ingredient-level hazards, and exposure potential. A full set of performance data are available for Profill System, as it is an existing commercial Priority Product. See Table 5.10 for more information on this product's performance.

4.3.2.2 High-Volume Low-Pressure (HVLP) Systems

A number of manufacturers have commercialized HVLP SPF systems. These products are still low-pressure SPF, but use specialized equipment that allows for higher volumes of foam to be applied. The products still require PPE to be worn (SFS, 2020).

For example, according to a 2020 article in *Spray Foam Magazine*, Spray Foam Systems' (SFS) Nitrosys products can offer high-volume outputs using a low-pressure system *via* a patented process called air nucleated static mixing and reduce re-occupancy time and PPE requirements (SFS, 2020). We identified a patent for this product (Patent No. US 0104709; Peters, 2018), but it only covers the mechanical features of the system and gives no information on its performance, formulations in which the product has been tested, or relative exposure potential. Nitrosys can be purchased and used as a standalone system or fitted onto a cart or Nitrosys spray rigs (SFS, 2020). Some product lines can use traditional SPF chemistry, whereas some cannot (*e.g.*, HVLP) (SFS, 2020). While the *Spray Foam Magazine* article notes that this system ensures lower exposure to MDI, the Nitrosys system still requires applicators to wear PPE, such as a full face mask, cartridge respirator, Tyvek suit, and gloves (SFS, 2020). The composition of Nitrosys/ICP HandiFoam® HVLP MD 2.0 was obtained from conversations with the supplier and the product's SDS (see Appendix A). The Nitrosys/ICP HandiFoam HVLP MD 2.0 formulation also contains several California Candidate Chemicals, including MDI (CAS No. 101-68-8), pMDI (CAS No. 9016-87-9), generic MDI (CAS No. 26447-40-5), and Stoddard solvent (CAS No. 8052-41-3) (CalDTSC, 2019a; ICP Building Solutions Group, 2019a,b). See Section 5 for more information on product-level emission and performance as well as information on ingredient-level hazards and exposure potential.

4.3.2.3 BASF Patents

BASF has two patents for approaches that lower exposure to unreacted pMDI/MDI in SPF – one granted in 2017 (Patent No. 9592516 B2) and another granted in 2019 (Patent No. WO 2019/089237 A1) (Wishneski *et al.*, 2017, 2019).

Patent No. 9592516 B2

This patent describes a two-component polyisocyanate system that mixes the two components in a static mixer prior to spraying using a non-gaseous pump and a "particular" spray nozzle (Patent No. 9592516 B2; Wishneski *et al.*, 2017). The patent describes a spray nozzle that uses the exact same process as traditional low-pressure SPF (*i.e.*, liquid chemicals are polymerized prior to leaving the SPF application gun in a static mixer). The patent primarily describes the mechanical configuration of the equipment and does not include information on the performance of the sprayed material. The patent describes the possible composition of the A- and B-sides (in very broad terms), which is very similar to the standard SPF formation (*i.e.*, MDI, polyester polyols, flame retardants, amine catalysts, surfactants, and HFC blowing agents). An example of a potential formulation is shown below.[13]

Example Formulation:

- pMDI (monomeric and oligomers) (CAS No. 9016-87-9)
- "Polyethylene terephthalate, diethylene glycol (DEG), phthalic acid, and/or terephthalic acid" (Wishneski *et al*., 2017). Note that a specific polyol was selected as a representative polyol (*i.e*., DEG [CAS No. 111-46-6]).
- "Phenol or nonylphenol, formaldehyde, and/or amines, one or more with propylene oxide and, optionally, ethylene oxide" (Wishneski *et al*., 2017). Note that a specific polyol was selected as a representative polyol (*i.e*., oxirane, 2-methyl-, polymer with oxirane, ether with 1,2,3-propanetriol [3:1] [CAS No. 9082-00-2]).
- "Sucrose, glycerin, propylene glycol, and/or propylene oxide" (Wishneski *et al*., 2017). Note that a specific polyol was selected as a representative polyol (*i.e*., sucrose, propylene oxide [CAS No. 9049-71-2]).
- Tetrabromo Phthalic Anhydride Diol (CAS No. 77098-07-8)
- tris-(Chloroisopropyl) Phosphate and/or Triethylphosphate (TEP) (CAS No. 78-40-0)
- "Combinations of tertiary amines of varying chemical structure" (Wishneski *et al*., 2017): Dimethylethanolamine (DMEA), triethylenediamine (TEDA), pentamethyldiethylenetriamine, and/or 2-{{2-(dimethylamino) ethyl}methylamino}-ethanol (no CAS Nos. identified).
- DABCO DC193 (no CAS No. identified)
- 1,1,1,1,1-Pentafluoropropane (no CAS No. identified)
- Water (CAS No. 7732-18-5)

According to the patent, limited tests of this system (*i.e.*, sprayed against a cardboard surface) indicate an approximate 50% reduction in air concentrations of "polyisocyanate," which is presumably MDI, measured 2.5 and 10 ft from the cardboard surface during 15 minutes of spray application (Wishneski *et al*., 2017). The air concentrations measured using this system were 23.3 parts per billion (ppb) at 2.5 ft from the surface (*vs.* 59 ppb for a typical application system) and 4.17 ppb at 10 ft from the cardboard surface (*vs.* 7 ppb for a typical application system). Note that the ACGIH TWA TLV for MDI averaged over an 8-hour period is 0.005 ppm or 5 ppb (ACGIH, 2019), so MDI concentrations at 2.5 ft still exceeded the TWA TLV and those at 10 ft were still below the TWA TLV (with the important caveat that the test was not conducted at an actual job site and the concentrations were measured after only a 15-minute application time). See Section 5 for available product-level performance information as well as ingredient-level hazards and exposure potential.

According to BASF, the equipment mentioned in this patent is commercially available for professional use as AutoFroth®. AutoFroth® equipment is primarily used for insulation applied in a factory (*e.g.*, during refrigerator or freezer manufacture). The equipment used to apply the foam is heavy and difficult to move.

[13] Trade names are given in the patent, but not CAS Nos. Gradient attempted to identify CAS Nos. for the various ingredients, but was unable to assign CAS Nos. for a few ingredients.

Additionally, the gun is generally mounted to other equipment to assist with moving. These limitations do not make it an ideal product for field application, because applicators typically hold the spray gun for extended periods of time. According to BASF, AutoFroth® has not been used as insulation for commercial and residential walls, basements, and roofs to date and more research is needed in order to adapt said technology for these purposes. Additionally, this formulation contains at least one California Candidate Chemical (*i.e.*, MDI, CAS No. 101-68-8) (CalDTSC, 2019a).

Patent No. WO 2019/089237 A1

This patent describes a two-component polyisocyanate system that mixes the unreacted MDI and hydroxyl functional polymer along with flame retardants, amines, silicone surfactant, catalysts, and blowing agents that minimizes MDI exposure based on the formulation chemistry (Patent No. WO 2019/089237 A1; Wishneski *et al*., 2019). An example of a potential formulation is shown below.[14]

Example Formulation:

- pMDI (monomeric and oligomers) (CAS No. 9016-87-9)
- Aromatic Polyester (*e.g.*, Terol 258, no CAS no. identified)
- GSP-280 (CAS Nos. 26301-10-0 and 9082-00-2)
- Tetrabromophthalate Diol (TBPD), a flame retardant (CAS No. 77098-07-8)
- Triethyl Phosphate (TEP) (CAS No. 78-40-0)
- Tegostab B8453 (no CAS No. identified)
- Dabco 33LV (CAS Nos. 25265-71-8 and 280-57-9)
- Dabco T (CAS No. 2212-32-0)
- Dimethylethanolamine (DMEA) (CAS No. 108-01-0)
- Dabco T120 (CAS No. 1185-81-5)
- Ethacure 100 (diethyltoluenediamine) (CAS No. 68479-98-1)
- Opteon 1100 (an HFO) (CAS No. 692-49-9)
- Water (CAS No. 7732-18-5)

This patent focuses on the viscosity of the agents and appears directed at minimizing the amount of MDI monomer while still maintaining the viscosity of the reactants in a range that supports application. However, the patent's formulation language is quite broad, *e.g.*, the viscosity of the MDI component is stated to range from 100 to 8,000 centipoise (cP), and the monomeric MDI content of the pMDI is stated to range from 10 to 90% by weight. The patent also describes an applicator system that pre-mixes the components prior to discharge at lower pressure. The patent claims that the system results in MDI emissions of less than 50 ppb MDI (and as low as 1 ppb). In one embodiment, emissions were measured at the applicator's location *via* a personal air sampler and at an area 3 ft behind the applicator. At the location of the applicator, average MDI emissions were reported as 12 with 10 air changes per hour (ACH) and 14 ppb with 20 ACH. In the area 3 ft behind the applicator, average MDI emissions were reported as 3.3 ppb with 10 ACH and 4.1 ppb with 20 ACH. No final product performance data are described in the

[14] Trade names are given in the patent, but not CAS Nos. Gradient attempted to identify CAS Nos. for the various ingredients, but was unable to assign CAS Nos. for a few ingredients.

patent. See Section 5 for more information on product-level emission as well as ingredient-level hazards and exposure potential.

4.4 Relevant Factors

We have considered the possibly relevant factors listed in the SCP regulations (22 CCR § 69505.5[c]; [CalDTSC, 2013]). Our review occurred in several stages. For many factors (notably the various toxicities specified in the SCP regulations [CalDTSC, 2013]), we had to tabulate data for the functional ingredients to understand if these factors differed materially among the evaluated products (the results of the data tabulation are discussed in Section 5). Based on our current knowledge of the properties of the different alternatives to the Priority Products we have identified, we have determined which factors are materially different between the Priority Products and any alternatives such that they would inform the conclusion of the Stage 1 AA. The conclusions we have reached in this regard are provided in Tables 4.1 and 4.2.

4.5 Relevant Product Use Information

The SCP regulations require information on volume of product sales in California as well as product use (duration, frequency). According to a confidential internal CPI report,[15] the volume of SPF sold in the western region of the US in 2019 was estimated to be 36.4 million pounds. In this report, the western region of the US was defined as Alaska, California, Hawaii, Oregon, and Washington. Information for California alone is not available. Regarding the use of the product, SPF application time is highly dependent on the size of the area to be insulated. According to the REs, typically, SPF installation for an attic would take less than a day, while installation for an entire newly constructed house could take one to two days; large houses or commercial buildings would take longer, up to a week or more. Spot filling of cracks and voids (an application for low-pressure SPF often called "weatherization") could take minutes. CalDTSC also suggested that we consult US EPA's Toxic Substances Control Act (TSCA) risk evaluation of 1,4-dioxane (US EPA, 2019a) for product use patterns. However, the information and references cited in the relevant portions of the 1,4-dioxane evaluation are not useful for answering these questions. For example, one reference was focused on asphalt roofing and not SPF. It should be noted that 1,4-dioxane is not an ingredient or impurity in SPF, contrary to the 1,4-dioxane evaluation. Concerning frequency, according to the REs, many insulation contractors install various types of insulation, not just SPF. As a result, it is difficult to ascertain actual use frequencies. It can be reasonably expected that insulation contractors install SPF on some days in a given week, but not every day.

4.5.1 Conceptual Model for Product Life Cycle

Figures 4.1, 4.2, and 4.3 show the conceptual exposure models for the life cycle of the Priority Products, non-MDI-based alternative formulations, and lower-exposure approaches, respectively. All three types of products have the same life cycle stages and thus, similar potentials for human and ecological exposures. The difference, to the extent that the available data permit it be determined, is a matter of degree.

Across the various life cycle stages (*e.g.*, manufacturing, processing, distribution, industrial use, commercial use, disposal) of the Priority Products, exposure to unreacted MDI (or its replacements) for chemical production workers, applicators, other workplace personnel, DIY applicators (for low-pressure SPF only), or residents *via* the inhalation and/or dermal contact exposure routes is possible. The reaction of MDI with polyols is known to be very fast, such that MDI emissions from SPF decline very rapidly with time (refer to data in Section 5.3) and are accounted for in manufacturers' recommended re-entry and re-

[15] Note this internal report is confidential to CPI and thus not provided in our reference list.

occupancy times. So, for MDI-based foams, exposures for workers not wearing PPE or wearing faulty PPE would be the primary concern. Exposure concern for workers applying high-pressure SPF products is primarily related to the inhalation of MDI vapors (due to MDI being heated to approximately 120°F during application of the product) and overspray mist or particulate (both an inhalation and dermal contact concern). For the non-MDI-based alternative formulations, very little information is available on how quickly the reactive chemistry cures and no information is available on whether there would be toxicological concern from the reacted foam. Wearing PPE and adhering to re-entry policies are still required for the lower-exposure approaches.

For all products, exposure to workers is expected to be low if appropriate PPE is worn during all work tasks and re-entry policies are followed. As noted above, for those workers not wearing the required PPE (or if PPE is worn incorrectly or malfunctions), inhalation exposures to vapor and aerosols/particulate are considered the most likely exposure route due to the physical and chemical properties of MDI and the reactive chemistries that are potential alternatives to MDI. Inhalation exposure potential is also decreased for the lower-exposure approaches, due to their use of physical barriers (*i.e.*, Profill System), their lower pressure (*i.e.*, HVLP), or their design such that SPF polymerizes prior to leaving the spray gun (*i.e.*, BASF Patent No. 9592516 B2; Wishneski *et al*., 2017), but is still high enough for all three to require wearing PPE during use. It is unclear from the patent how the lower-exposure approach described in BASF Patent No. WO 2019/089237 A1 results in lower MDI emissions (Wishneski *et al*., 2019). For all products, there is also the potential for inhalation exposure to hazardous airborne thermal degradation products from SPF. When heated above normal processing temperatures, such as happens when grinding, sawing, or welding near SPF, exposure to carbon dioxide, nitrogen oxides, hydrogen cyanide, isocyanates, amines, and hydrocarbons is possible (ACC, 2014). It should be noted that any organic material, including the possible alternatives, would release most of the abovementioned chemicals when undergoing thermal degradation.

There is also the potential for dermal exposures in various worker scenarios (*e.g*., cleaning spraying equipment, over-spray), assuming individuals do not wear appropriate PPE as required by law and stipulated by the manufacturers (or if PPE is worn incorrectly or malfunctions). Significant oral exposures *via* the transfer of MDI from hand to mouth are unlikely due to the volatility of heated MDI, assuming that PPE is worn correctly and that good work practices are followed. Workers' hands coming into contact with foam would be most common during the trimming stage, at which point the foam is cured and unreacted MDI is no longer available for volatilization. The potential for exposure during SPF application is expected to be similar for any alternative formulation, as the ingredients have to be quickly reactive (*i.e.*, exhibit high reactivity) in order to form an effective foam. It would be important to understand the hazards of the non-MDI-based alternative formulations in the context of PPE; workers applying the Priority Products are required to wear PPE, and if alternatives are also highly reactive and volatile, one might expect wearing PPE to be required for these alternatives as well. Thus, this critical question regarding potential worker exposure requires an understanding of the relative chemical hazards of the Priority Products and the possible alternatives.

Reacted SPF is a non-hazardous household waste, and thus, reacted SPF would have no significant impact on human health, environmental receptors, air, or soil during trimming, end-of-life disposal, or other disposal scenarios. As CalDTSC has stated, reacted SPF, if disposed of into storm sewers or other water bodies, could create a physical obstruction, but this is true of any other type of construction debris or other materials, such as packaging. Although no information is available on the appropriate disposal practices for reacted non-MDI-based SPF, there is no reason to expect that it would be hazardous waste.

There may be residual unreacted material in the drum that could be a source of potential exposure, but unused high-pressure SPF material can be saved and used for the next job for which it is required. The same would be true for the lower-exposure alternatives. For low-pressure SPF, unused A- and B-side material should be disposed of according to the manufacturer's recommendations, in addition to any federal, state, and/or local regulations. The REs understand that the applicators' general practice is that small amounts of residual chemicals are reacted to produce foam, which can then be disposed of, typically as non-hazardous waste/construction debris (ACC, 2019a). These types of exposures would be expected to be similar for the non-MDI-based alternative formulations, although this is not certain based on the available patent information (*i.e.*, anticipated disposal procedures are not discussed in the patents).

While it is possible that unreacted SPF could enter storm sewers or other environmental media through accidental spill, leaks, or improper disposal, this would be against the disposal instructions noted on products' SDSs and other product information. Presumably, the same applies for the unreacted ingredients described in the non-MDI-based patents. In these unlikely scenarios (*i.e.*, accidental spill, leaks, or improper disposal), the unreacted SPF and non-MDI-based patent ingredients (and their transformation products) may have adverse impact on the environment.

4.6 Life Cycle Segments

4.6.1 Raw Materials Extraction

To understand the potential impacts of raw materials extraction, it is necessary to understand how the chemical components of the Priority Products and the possible alternatives are produced. The results of a review of manufacturing process information for the key functional ingredients in the Priority Products, the non-MDI-based alternative formulations, and the lower-exposure approaches are shown in Tables 4.3-4.5.[16] Most of the information discussed in these tables was obtained from the Hazardous Substances Data Bank (HSDB; NLM, 2020). As discussed in the tables, most of the chemicals used in the Priority Products and possible alternatives are likely produced from fossil-fuel-based sources. For example, MDI/pMDI is produced *via* the reaction of aniline with formaldehyde to produce methylene dianiline (also called diphenylmethane diamine), which is in turn reacted with phosgene to produce MDI (ACC, 2019b). Aniline is obtained *via* the nitrosation of benzene with subsequent hydrogenation (NLM, 2018a). The benzene can be expected to be derived from fossil fuel sources. Formaldehyde is produced *via* the catalytic oxidation of methanol, which is itself typically derived from synthesis gas (syngas), which is produced from fossil fuel sources (NLM, 2015; GSTC, 2020). It should be noted that some REs have formulations that involve a polyol component derived from renewable resources (Hardcastle, 2015). For example, some products use biologically derived polyols, namely sucrose (*i.e.*, sugar), as a major component. In addition, some REs derive polyester polyols from recycled polyester terephthalate (from plastic bottles). Similar bio-based sources are also viable for the lower-exposure approaches. For example, sucrose is used as a component of Profill System. Bio-based sources are also found in one of the non-MDI-based alternative formulations (sucrose and glycerin are used in the Firestone/Gaco Canary product, as the acetoacetate esters of these chemicals). These same renewable feedstocks likely cannot be used in the other non-MDI-based alternative formulations, which are based on different chemistries; whether there are bio-based alternatives to the chemicals specified in those patents is unknown. It should be noted that the functional ingredients of a number of the non-MDI-based alternative formulations are formulated from acrylates, polycarbamates, or BPA resins. Most of these chemicals are also synthesized from fossil fuel sources. For example, BPA is produced by the reaction of acetone with phenol (NLM, 2018b), and phenol itself is variously produced from benzene, toluene, or cumene (NLM, 2003), all of which are derived from petrochemical sources. Similarly, acrylic acid is formed *via* reactions with propylene-, ethylene-, or other fossil-fuel-based (typically natural gas) starting materials (NLM, 2018c).

[16] The tables do not include the NanoSonic product, because information on its chemical composition was not located.

A life cycle assessment (LCA) of SPF developed by thinkstep contains some notable information concerning the raw materials extraction phase of the SPF life cycle (thinkstep, 2018). For all of the SPF types evaluated, the raw material extraction stage (Module A1 in thinkstep, 2018) contributes the most to ozone-depleting potential (ODP), acidification potential (AP), eutrophication potential (EP), smog-formation potential (SFP), and abiotic depletion potential (ADP) relative to other life cycle stages.[17] One key limitation of the thinkstep LCA is that it discusses the relative impacts of SPF across different life cycle stages but does not put the individual life cycle impacts in context (*e.g.*, in comparison to other industrial processes). Thus, the finding that raw materials extraction was the life cycle stage with the largest impacts does not provide an indication of how these impacts compare to other types of industrial processes (*e.g.*, production of other products used in homes). More importantly, an LCA is not available for either the non-MDI-based alternative formulations or the lower-exposure approaches. On a theoretical basis, the raw materials extraction impacts of the lower-exposure approaches would be expected to be similar to those of the traditional SPF evaluated in the thinkstep LCA, although these approaches do require some additional equipment (notably, the plastic sheeting or aluminum guides involved with Profill System). Whether such differences constitute *material differences* cannot be determined in the absence of an LCA specific to the lower-exposure approaches. For the non-MDI-based alternative formulations, there is no way to make comparisons to the traditional SPF evaluated in the thinkstep LCA in terms of potential raw materials impacts.

Overall, we found no information suggesting a material difference between the Priority Products and possible alternatives in terms of raw materials extraction impacts. Some formulations of the Priority Products are based on renewable materials, and these same ingredients could feasibly be used (or are used) in the lower-exposure approaches. These may not be an option for some of the non-MDI-based alternative formulations, although the data to clearly support this conclusion is limited due to the preliminary nature of the formulations. Importantly, all of the products contain ingredients that are derived from fossil fuels. We conclude that there are unlikely to be material differences among the possible alternatives, but data allowing us to make this determination with certainty are not available.

4.6.2 Resource Inputs and Other Resource Consumption

The thinkstep LCA characterizes resource inputs for SPF production, such as energy, water, and other material requirements (thinkstep, 2018). The greatest energy, water, and other raw material inputs, by at least an order of magnitude, are associated with the raw materials extraction and manufacturing phases of SPF's life cycle (Modules A1-A3 in thinkstep, 2018). The next most resource-intensive segments of SPF's life cycle involve transportation of the formulated product to users and its installation; regarding the latter, thinkstep (2018) states that the use of diesel generators to power the SPF installation equipment is a significant factor. According to one RE, one MDI manufacturer employs processes that produce heat and other processes that require heat; they use heat recovery to "recycle" energy. This manufacturer's process also produces chlorine containing byproducts, which are captured and processed to generate new chlorine to be used as a raw material. Thus, some approaches to limit resource inputs and consumption are employed in SPF production. Whether these could be equally employed with the possible alternatives is unknown.

Although they have similar characteristics as the Priority Products, the lower-exposure approaches are not covered by the thinkstep LCA, which was based on generic SPF, and no LCA specific to the lower-exposure approaches was identified. No LCA is available for the non-MDI-based alternative formulations, which is not surprising, given that these products are still in the development stage (or potentially no longer under development). Thus, there is insufficient information to compare this life cycle stage of the Priority

[17] All citations to information from the thinkstep LCA refer to low global warming potential (GWP) HFO products, as the HFC products evaluated in the LCA are no longer permitted to be sold in California.

Products and that of the possible alternatives and the potential for a material difference to be present is unclear.

4.6.3 Intermediate Materials Processes

A review of the chemical manufacturing processes for the Priority Products and potential alternatives (Tables 4.3-4.5) identified a number of chemical intermediates in the production of these products' functional ingredients. It should be noted that production of the Priority Products and any possible alternatives is expected to take place in closed reaction vessels, with minimal potential for human exposure. That being said, the production of MDI/pMDI and other ingredients used in the Priority Products and the lower-exposure approaches does involve chemicals that are of potential concern (*e.g.*, listed under California's Proposition 65). In this regard, the Priority Products and the lower-exposure alternatives are not materially different. For example, all the Priority Products include MDI/pMDI, with the same intermediates (*i.e.*, methylene dianiline). With respect to the non-MDI-based alternative formulations, many of these involve new chemistries, and synthesis pathways are not discussed in the patents. Even so, when production information is known or can be inferred based on chemical class information, the processes similarly involve chemicals that are of potential concern. For example, chemicals involved in the synthesis of the key functional components include BPA, formaldehyde, epichlorohydrin, and methanol, all of which are listed under California Proposition 65 (UL LLC, 2020). Thus, although information on the potential alternatives is limited, it appears unlikely that they would differ materially from the Priority Products in terms of intermediate materials impacts.

The thinkstep LCA of SPF (thinkstep, 2018) does not discuss intermediate materials processes; if these are included in the LCA, their impacts are not separately identified.

4.6.4 Manufacture

As noted above, MDI is typically produced by the reaction of aniline and formaldehyde to produce aromatic diamines, which are subsequently reacted with phosgene to yield a mixture of MDI and pMDI. Specific MDI isomers are isolated from this technical mixture *via* fractional distillation. As shown in Tables 4.3 and 4.5, the functional ingredients of the lower-exposure approaches are largely the same as those of the Priority Products, whereas those of the non-MDI-based alternative formulations (Table 4.4) are quite different. However, with a few exceptions, the chemicals used in all the identified possible alternatives appear to be produced industrially from chemical feedstocks and would be produced in facilities that must adhere to occupational exposure standards. This suggests that, at least qualitatively, it is unlikely there is a material difference among the alternatives; however, there is insufficient information to address this question (particularly for the non-MDI-based alternative formulations).

The thinkstep LCA of SPF contains information concerning manufacturing requirements such as the amount of renewable and non-renewable energy and water consumed during the production of SPF in general (thinkstep, 2018). However, the thinkstep report does not allow one to make predictions about similar manufacturing requirements for the alternatives. Given that all the lower-exposure approaches contain many of the same ingredients, one might expect the manufacturing impacts in terms of energy and other resource consumption would be similar between them, it appears unlikely there would be a material difference in this regard, although available data with which to assess this are limited. No inference can be drawn regarding the non-MDI-based alternative formulations, as they largely involve different chemistries.

4.6.5 Packaging

There appears to be no evidence of any material difference between the Priority Products and the various possible alternatives in terms of the type of packaging that would be used for them. The lower-exposure approaches are packaged in similar containers as the Priority Products, although some (*e.g.*, Profill System) require additional packaging for the plastic sheeting or aluminum guides, and HVLP would require additional packaging for the disposable nozzles. Whether these would materially increase the impacts of product packaging has not been quantified. No specific information on the packaging of the non-MDI-based alternative formulations is available, as these have not progressed to the stage in which packaging would be determined. On a theoretical basis, all of the proposed non-MDI-based alternative formulations consist of two "sides" that must be combined in order to produce spray foam. Several of the patents describe an advantage of the formulations being that existing application equipment can be used for them, which implies they have similar pressures and, therefore, would require similar containers. All versions of the Priority Products are typically sold in metal cylinders of different sizes. According to the REs, high-pressure SPF products are typically sold in 55-gallon drums for use in special equipment (*i.e.*, spray rig trucks), while low-pressure SPF products are sold in smaller two-cylinder kits, which include the application equipment. Given what is known from the patents regarding the non-MDI-based alternative formulations and from marketing literature for the lower-exposure approaches, such alternative products would not require materially different packaging from the Priority Products.

The thinkstep LCA of SPF considered product packaging in its analysis; Table 3-5 in that report provides the assumptions made in the assessment regarding the extent to which different types of packaging are available (thinkstep, 2018). The report also lists the masses of different packing materials (steel drums, pallets, plastic wrap) used for products in terms of per 1,000 kg of B-side produced. However, further details on the environmental impact specifically associated with SPF product packaging are not provided in the report.

Overall, packaging impacts would not appear to be materially different among the possible alternatives and the Priority Products (*i.e.*, given that all involve two "sides" of ingredients that must be packaged separately). Packaging for the non-MDI-based alternative formulations is uncertain, because they have not reached the development stage that would involve designing packaging. Profill System, which requires additional materials, may have additional packaging impacts, but these have not been quantified by an LCA, and thus, whether they constitute a *material difference* is not clear.

4.6.6 Transportation/Distribution

The thinkstep LCA (thinkstep, 2018) describes the transportation impacts associated with SPF. The report indicates that the transportation of raw materials to the formulation site (Module A2) and the transportation of the product to the customer (Module A4) are minor contributors to the various life cycle impacts of SPF relative to the impacts of raw materials extraction and installation (thinkstep, 2018). For example, for closed-cell foams formulated with low-GWP blowing agents, the two transportation stages of their life cycle appear to contribute approximately 5% of the total life cycle GWP impact and have similarly minor contributions to other life cycle impacts (thinkstep, 2018, Figure 4-6). Transportation of the products at the end-of-life stage (*i.e.*, to landfills or other disposal/recycling centers) appears to account for less than 1% of their overall life cycle impacts. Similar conclusions were provided for other HFO-based SPF products.

No equivalent LCA (or similar analysis) was located for the non-MDI-based alternative formulations, and thus, comparing their transportation/distribution impacts to those of the Priority Products is not possible. For example, it is not clear where such products would be produced and thus what the transportation distances and related environmental impacts would be.

Product-level information on the Priority Products indicates that they are not considered to be "Dangerous Goods" by the United States Department of Transportation (US DOT). However, similar product-level information is not available for the non-MDI-based alternative formulations. While product-level information would eclipse ingredient-level information, all of the possible alternatives contain at least one chemical that would be classified as a "Dangerous Good" under the US DOT regulations (US DOT, 2019). Based on their understanding of the industry, the REs would expect that these would be similar between the Priority Products and the possible alternatives, but data with which to make a definitive determination are not available. In addition, there are no data in the patents indicating that the alternatives offer substantially higher efficacy at a reduced weight/volume or eliminate a transportation step in the supply chain. Given the uncertain nature of the information on product composition for some of the alternatives, the relevance of this life cycle stage is unclear.

4.6.7 Use/Application

The use phase for SPF includes installation. The thinkstep LCA of SPF indicates that installation of SPF is a significant contributor to its overall life cycle impact, attributing this to the use of diesel generators to operate equipment during its installation (thinkstep, 2018). For example, for closed-cell foams formulated with low-GWP blowing agents, the installation phase of the life cycle appears to contribute approximately 15% of the total life cycle GWP impact (thinkstep, 2018, Figure 4-6). The life cycle impact for which the use/installation phase contributes the largest component is the potential for smog formation (presumably also due to the use of diesel generators for SPF installation), which is only slightly lower than that contributed by raw materials extraction. A similar pattern is seen for the other HFO-based foams that were evaluated. The thinkstep LCA also discussed off-gassing of foams during their lifetime as part of the use phase of their life cycle, but apparently only focuses on the blowing agent in the SPF formulation. Blowing agent emissions appears to contribute a negligible amount to SPF's overall life cycle impact, particularly among HFO-based products, which are the only SPF products currently allowed to be sold in California. The REs anticipate that emissions would be similar for potential alternatives that contain gas blowing agents.

As no LCA exists for the non-MDI-based alternative formulations and lower-exposure approaches, no definitive comparisons between these alternatives and the Priority Products are possible for this life cycle stage. Presumably, all would require similar use of diesel generators for installation, so that aspect of the installation impacts would be comparable for all products. On a more theoretical basis, use is one area in which the potential alternatives could significantly differ from the Priority Products. As noted above, the rate of curing and the volatility of unreacted MDI or alternative chemistries could impact the exposures to applicators, other workers, and residents, although these could be addressed by amended re-entry and re-occupancy times. There is no difference in post-application MDI emission between the generic formulae for the Priority Products (Groups 1, 2, and 3) and Nitrosys/ICP HandiFoam HVLP MD 2.0 (Group 1). As described in Table 5.11, exposure to MDI during application was lower with Firestone/Gaco ProFilm (0.0076 ppm) and ProWeb (0.0010 ppm) products compared to standard low-density high-pressure SPF (0.3 ppm, for the Group 2 generic formula), but these measurements were taken in only a single study, which was done without ventilation. In the Wishneski *et al*. (2017) patent, exposure to MDI during application was lower for the described application system compared to a "generic application system," but ventilation was not mentioned in the patent, and the study was conducted in a laboratory rather than an actual field setting. In the Wishneski *et al*. (2019) patent, with active ventilation and during application, MDI emission was approximately half that of generic high-pressure medium-density SPF; nearly the same as that of generic high-pressure, low-density SPF; and several times higher than that of generic low-pressure SPF. However, not enough information is available on BASF Patent No. WO 2019/089237 A1 to assign the correct comparable product grouping (Wishneski *et al*., 2019). Ultimately, all of the lower-exposure approaches are still Priority Products and require applicators to wear appropriate PPE during use.

It is unclear how exposure during the installation of the non-MDI-based alternative formulations could differ, as these have not been studied. It is expected that all the alternative formulations and lower-exposure approaches would use similar application equipment (spray rigs/spray guns) as the Priority Products and would have similar potential for exposure during cleaning and maintenance of the equipment. We can assume that these (or the Priority Products) could be redesigned to use equipment that minimizes exposure to MDI or equivalent functional ingredients. Such design work would typically be done when products are closer to commercialization. It is also the case that some of non-MDI-based alternative formulations pose different hazards relative to the Priority Products, and these particular hazards may therefore be relevant factors for the use and application phase of the SPF life cycle. However, as noted earlier, specifics on these formulations come from patents and is not definitive; thus, this life cycle stage appears to be potentially relevant, but this cannot be determined with certainty.

An evaluation of the life cycle impact of SPF in the use phase also requires consideration of its benefit to the user and environment in terms of increased energy efficiency and reduced carbon dioxide (CO_2) emissions. SPF improves the energy efficiency of buildings by insulating and air sealing the thermal envelope. The gains in energy efficiency have a positive impact on the environment *via* reduction of greenhouse gas emissions during the production of energy for electrical power and the conditioning of air. The SPFA conducted an LCA and use-phase environmental impact study on SPF insulation in 2018 (Sustainable Solutions Corp., 2002). The LCA compared homes insulated per the 2018 IECC with a standard insulation package and SPF in Minneapolis, Houston, and Richmond. Air leakage for the standard insulation package was assumed to be the maximum allowed by the 2018 IECC (3 or 5 air changes per hour at 50 pascals [Pa] pressure differential [ACH_{50}]). Air leakage for the SPF insulation option was assumed to be 1.5 ACH_{50} based on blower door test data for homes insulated entirely with SPF. The study compared the environmental impacts of the standard insulation manufacturing and use phase to those of the SPF insulation manufacturing and use phase. To understand how this environmental recovery ("payback") period is calculated, consider the following example for GWP from high-pressure closed-cell SPF in installed beneath the roof deck (unvented attic) in Houston, Texas (Sustainable Solutions Corp., 2002).

- The initial GWP *contribution* from the high-pressure closed-cell SPF insulation is 9,733 kg CO_2.
- The initial GWP contribution from the standard insulation is 2,528 kg CO_2.
- The additional GWP *reduction* from SPF used under the roof deck instead of traditional insulation on the attic floor is 867 kg CO_2/year.
- The GWP payback is simply the GWP impact of the SPF minus the GWP impact of the standard insulation, then divided by the annual GWP reduction obtained from using SPF:

  (9,733 - 2,570) / 867 or 8.3 years.

In other words, the environmental impact of SPF, compared to standard insulation, is made up in 8.3 years of use for closed-cell HFO formulations. After 8.3 years, it is more environmentally beneficial to use SPF compared to traditional insulation, due to the increased efficiencies from air sealing. Given that the lifespan of SPF insulation is approximately 75 years (thinkstep, 2018), homeowners in this study are making a positive contribution to the environment for 66.7 years. No similar information is available for the possible alternatives, although if they meet similar R-value and lifespan requirements, the benefits would likely be similar.

4.6.8 Operation and Maintenance

This life cycle stage is not materially relevant to this Abridged AA, as the Priority Products are applied and then passively provide insulation without the need for maintenance. The same would be expected for the possible alternatives. Moreover, the cured foam is inert from the standpoint of MDI/pMDI, the chemical of concern that constitutes the basis for the Priority Product listing (CalDTSC, 2014). SPF used in roofing applications may need to be renewed with a new coating 10 to 15 years after first installation (Schenke, 2014). However, the coating is applied without impacting the roofing material and would not involve unique maintenance factors that would make this stage of the life cycle a relevant concern. All other forms of SPF were assumed in the thinkstep LCA to have a 75-year lifespan (thinkstep, 2018).

This life cycle stage is not addressed by the thinkstep LCA of SPF, which instead includes the use life cycle stage (thinkstep, 2018).

4.6.9 Waste Generation and Management

The thinkstep LCA of SPF provides limited information regarding waste generated during the formulation or production of SPF (thinkstep, 2018). Table 3-3 of the LCA report notes that, based on information collected from participating SPF formulation facilities, there are roughly 4.5 kg of waste generated per 1,000 kg of B-side material produced, the disposal of which is evenly split between incineration and deposition in a landfill (thinkstep, 2018). The report also notes: "The side-B blending process utilizes internal scrap from its own operations. Additionally, many facilities utilize technology to minimize the release of gaseous material inputs, such as blowing agents, during material transfer and processing. Waste materials are typically reintegrated into the formulation without additional collection, transport, or processing" (thinkstep, 2018). It is assumed, based on conversations with the REs, that similar processes are in place to control waste production for MDI/pMDI production. Thus, there is minimal waste generation associated with the generation of the Priority Products. For example, for high-pressure SPF, any unreacted material is manually transferred into new containers. MDI and the B-side materials are not classified as hazardous waste (see Section 7.1.1). Based on their similar chemical composition, one would expect the lower-exposure alternatives to be similar. As the non-MDI-based alternative formulations are not being produced commercially, there is no basis for discussing their waste generation potential or how any generated waste would be managed. There is no mention of different waste generation or waste management requirements in the patents, and thus, it appears unlikely that there is a material difference among the possible alternatives in this area.

CalDTSC has also raised the issue of waste generation associated with trimming installed (but not yet fully cured) foam. One of the lower-exposure approaches (Firestone/Gaco Profill System) does appear to require less trimming or other cleanup activity as a result of the plastic sheeting or aluminum guides that are used during foam installation. The REs note that open-cell SPF is trimmed, whereas closed-cell SPF is not typically trimmed. Whether this constitutes a *material difference* is unclear. We have found no information indicating a difference in post-installation waste for the other lower-exposure products. Data are lacking concerning the amount of trimming or post-processing that would be required for the non-MDI-based alternative formulations.

4.6.10 Reuse and Recycling

The thinkstep LCA notes that "SPF cannot be recycled like other plastics" (thinkstep, 2018). As noted in Section 4.6.1, some SPF products currently use recycled plastics in production (typically in some chemicals present on the B-side), but the end product (*i.e.*, cured foam) is currently not recyclable. Data are lacking with which to determine if the same is possible for the non-MDI-based alternative formulations. Given the similarity in ingredients, one would expect the same to apply for the lower-exposure approaches. We found no information concerning the reuse or recycling potential of the non-MDI-based alternative formulations. Recyclability was not discussed in any of the patent documents for the alternative formulations. Overall, it appears unlikely that there would be a material difference in terms of reuse and recycling between the Priority Products and the possible alternatives, although the available data with which to assess this are limited.

4.6.11 End-of-Life Disposal

There is no discussion in the thinkstep LCA of SPF regarding unused, unreacted product. The thinkstep LCA assumes that when buildings are decommissioned, insulation foam is removed manually, and thus, there are life cycle impacts from this activity (thinkstep, 2018). The LCA further assumes that waste materials are transported 30 miles for landfill disposal as mixed construction waste. As shown in Figures 4-2, 4-4, 4-6 and 4-7 of thinkstep (2018), waste disposal (Module C4) is a negligible contributor to the overall life cycle impact of SPF.

All unused A- and B-side materials (for either the identified possible alternatives or the Priority Products) are required to be properly disposed of according to federal, state, and/or local regulations. For high-pressure SPF, because containers can be resealed, unused material can be saved and reused for the next job for which they are required. For low-pressure SPF, unused A- and B-side material should be disposed of according to manufacturer's recommendations, in addition to federal, state, and/or local regulations. The REs understand that the applicators' general practice is that small amounts of residual chemicals are reacted to produce foam, which can then be disposed of, typically as non-hazardous waste/construction debris (ACC, 2019a). While it is possible that unreacted product could be improperly disposed of into storm sewers or other media, this would be against the instructions noted on the SDS and other product information. When reacting with water, MDI forms insoluble polyurea. The reaction products of the non-MDI-based alternative formulations are not known. As CalDTSC has stated, reacted product, if disposed of into storm sewers or other bodies, could create a physical obstruction, but this is true of any other type of construction debris, or indeed, other materials such as packaging. As noted above, cured SPF that is removed from a home is disposed of as solid waste or construction debris, because the foam is fully reacted and would not be a hazardous waste product. It can be expected that any alternative would have similar properties, because an alternative that produced a cured foam that required management as hazardous waste would face substantial hurdles to adoption. Overall, it appears unlikely that there would be a material difference in terms of end-of-life disposal between the Priority Products and the possible alternatives, as any product that could not be conserved for later use or which would require more stringent disposal considerations would likely not meet with market acceptance.

Table 4.1 Consideration of Potentially Relevant Factors Identified in the SCP Regulations

Category	Factor that Is Relevant if Materially Different Between Products[1] (*i.e.*, Priority Products and Alternatives)	Relevant?[2]	Basis
Life Cycle Segments	Raw materials extraction	Unlikely, but data are limited	While there is an LCA for SPF that characterizes resource inputs such as energy, water, and other material requirements (thinkstep, 2018), which is directly applicable to the Priority Products, no equivalent LCA or similar document was identified for the potential alternatives. The Priority Products and some lower-exposure approaches have polyols obtained from renewable or bio-based materials (*i.e.*, sucrose or soy-based polyol), and it is not clear if this would be the case for any of the non-MDI-based alternative formulations, other than Firestone/Gaco Canary™, which uses a sucrose-based functional ingredient (Trumbo *et al*., 2016). Other functional ingredients (*i.e.*, MDI and some polyols and their functional equivalents in some of the non-MDI-based alternative formulations) appear to be obtained from fossil fuel sources (based on Tables 4.3-4.5). A review of general information on chemical production for the functional ingredients in the products (Tables 4.3-4.5) suggests that there are no material differences between them, but this analysis reflects general information, not specific production data.
	Resource inputs and other resource consumption	Unclear	There is no LCA available for the possible alternatives that quantifies resource (*e.g.*, water, energy) use during their production. This parameter may be similar for the lower-exposure approaches (which are MDI based) but the non-MDI-based alternative formulations are different and not produced at the same scale as the Priority Products. No data are available for the non-MDI-based alternative formulations.
	Intermediate materials production processes	Unlikely, but data are limited	A review of information on the chemical precursors of the functional ingredients in the Priority Products and possible alternatives (as summarized in Tables 4.3-4.5) suggests that there are no material differences in terms of the hazards of chemical intermediates, but this analysis reflects general information and not final formulations for some products. See Section 4.6.3 for further details.

Category	Factor that Is Relevant if Materially Different Between Products[1] (*i.e.*, Priority Products and Alternatives)	Relevant?[2]	Basis
Life Cycle Segments	Product manufacture	Unlikely, but data are limited for lower-exposure approaches; Unclear for non-MDI-based alternative formulations	All the products appear to have some hazardous ingredients involved in their manufacture (Tables 4.3-4.5). Because the lower-exposure alternatives are also MDI based, the hazards/impacts of these would be expected to be similar to those of the Priority Products. As noted in Section 4.6.4, the exact formulations of the possible alternatives are not currently known. There are significant data gaps concerning their hazards (refer also to Section 5).
	Packaging	Unlikely, but data are limited	All of the products, approaches, and formulations have two "sides," and thus all would require similar packaging. Thus, a material difference between the products in this regard is considered unlikely. Whether the additional packaging required for a product like Firestone/Gaco's Profill System™ (with plastic sheeting or aluminum guides; Gaco Western, 2017b, 2020) constitutes a material difference is unclear in the absence of an LCA for that product.
	Transportation during and between all life cycle segments	Unclear	The LCA for SPF indicates that transportation has the most life cycle impacts during the raw materials extraction and manufacturing phases of the SPF life cycle (thinkstep, 2018). No LCA exists for the possible alternatives, but substantial differences in transportation would be not be expected for the alternatives based on the types of chemicals involved and the product characteristics (*e.g.*, the products are each a set of two drums of reactants). Based on their understanding of the industry, the REs would expect that transportation and distribution impacts would be similar between the Priority Products and the possible non-MDI-based alternative formulations, but if new production is required to address the California market specifically (*e.g.*, producing different products than are produced nationally), then transportation and distribution impacts could be increased. In the absence of an LCA for the potential alternatives, no clear determination is possible.
	Distribution	Unclear	

Category	Factor that Is Relevant if Materially Different Between Products[1] (*i.e.*, Priority Products and Alternatives)	Relevant?[2]	Basis
Life Cycle Segments	Use	Potentially, due to exposure potential; Unlikely, due to environmental impacts	The lower-exposure approaches have potential differences in exposure during application relative to the Priority Products, although whether the magnitude of the differences constitutes a material difference is unclear. Data are lacking concerning exposure during the use phase for the non-MDI-based alternative formulations, although each of these contains chemicals that would likely be of concern to CalDTSC, and many have significant data gaps concerning their hazards. In terms of the positive environmental impacts of using SPF, given the building code requirements and market pressures, it is likely that any viable alternative would produce similar insulation and thus would have a similar environmental benefit.
	Operation and maintenance	NA	Not applicable to this product type. The product is applied and passively provides insulation.
	Waste generation and management	Unlikely, but data are limited for lower-exposure approaches; Unclear for non-MDI-based alternative formulations	During SPF production, waste is minimized by recycling material back into the production process. As noted in Section 4.6.9, the small amount of waste MDI and B-side materials produced is not classified as hazardous waste, and the same would be true for the lower-exposure approaches, which are also MDI based. Data are lacking for the non-MDI-based alternative formulations. There is no indication that production of the potential alternatives involves some other process (*e.g.*, catalysis) that reduces waste generation (*e.g.*, this is not mentioned in the patents reviewed).

Category	Factor that Is Relevant if Materially Different Between Products[1] (*i.e.*, Priority Products and Alternatives)	Relevant?[2]	Basis
Life Cycle Segments	Reuse and recycling	Unlikely, but data are limited	As noted in Section 4.6.1, some SPF products currently use recycled polyethylene terephthalate in the production of polyols. This could be true of the lower-exposure approaches as well. Data are lacking to determine if the same is possible for the non-MDI-based alternative formulations. These are addressed under resource inputs and consumption. However, for all the products, the end product (cured foam) is not expected to be recyclable, and it is expected that any unused unreacted product could be retained (given shelf life requirements) and used for future jobs.
	End-of-life disposal	Unlikely, but data are limited	Unused product would presumably be disposed of as required by federal, state, and local regulations and according to manufacturer directions. Alternatively, for high-pressure SPF, unused product could be retained and used for future work for which it is required. Unused product could also be combined to produce foam that can be disposed of as inert solid waste. The same is true of the lower-exposure approaches. There is no mention of disposal in the patents for the non-MDI-based alternative formulations, but given the similar product approach (*i.e.*, two reactive sides that are combined to produce an inert material), the same end-of-life disposal methods are reasonably expected to apply for these alternative formulations.
Adverse Air Quality Impacts	Would the product bring any changes to emissions of California Toxic Air Contaminants (*e.g.*, benzene, Cr[VI])?	Potentially	Based on a review of the California Toxic Air Contaminant list (CARB, 2020), only the Priority Products and one of the formulations contains chemicals present on the list (*i.e.*, MDI in the Priority Products and BPA in the Owens Corning formulation [Olang, 2012]). MDI is listed as a federal Hazardous Air Pollutant pursuant to the federal Clean Air Act and as a Toxic Air Contaminant pursuant to the California Health and Safety Code Section (CARB, 2020). This endpoint may be relevant because the other non-MDI-based alternative formulations do not contain any California Toxic Air Contaminants, to the best of our knowledge based on their patent information.

Category	Factor that Is Relevant if Materially Different Between Products[1] (*i.e.*, Priority Products and Alternatives)	Relevant?[2]	Basis
Adverse Air Quality Impacts	CO_2 emissions	Unclear	As noted in Section 4.6.2, an LCA exists for SPF that describes carbon dioxide (CO_2) emissions (thinkstep, 2018). However, a similar assessment does not exist for any of the alternatives. Thus, no data on this parameter are available for a comparison.
	HFC emissions	No	Many of the low-pressure and medium- and high-density SPF products, as well as some potential alternatives, use or have used HFCs as blowing agents. This would be common to both the Priority Products and any alternatives. HFCs are being replaced in SPFs sold in California for most uses starting in 2020, due to their prohibition in the state (CARB, 2018a). Thus, it is assumed that there is no material difference between the Priority Products and possible alternatives for this parameter.
	Methane emissions	Unlikely, but data are limited	Based on the known production process for MDI as well as available chemical ingredient information for the non-MDI-based alternative formulations, emissions of these chemicals are not expected to be part of the life cycle of the Priority Products or any of these alternative formulations. However, there is no LCA for the non-MDI-based alternative formulations with which to substantiate the assumptions.
	Nitrogen fluoride emissions		
	Perfluorocarbon emissions		
	Sulfur hexafluoride emissions		
	Other global warming gas emissions	No	All the ingredients of the Priority Products and non-MDI-based alternative formulations are produced industrially. Other than the HFCs used as blowing agents (which are being replaced with low-global-warming-potential HFOs in SPFs sold in California, due to their prohibition in the state [CARB, 2018a]), no other greenhouse gases are known to be involved in the SPF life cycle.
	Nitrogen oxide emissions	Unlikely, but data are limited	Based on the known production process for MDI as well as available chemical ingredient information for the non-MDI-based alternative formulations, emissions of these chemicals are not expected to be part of the life cycle of the Priority Products or alternative formulations. None of the functional ingredients in the Priority Products and alternatives are ozone-depleting substances (Table 5.4).
	Particulate matter emissions		
	Ozone-depleting substances emissions[3]		
	Sulfur dioxide emissions		

Category	Factor that Is Relevant if Materially Different Between Products[1] (*i.e.*, Priority Products and Alternatives)	Relevant?[2]	Basis
Adverse Air Quality Impacts	Would the product bring any changes to emissions of compounds that might lead to tropospheric ozone production?	Potentially	Some, but not all, of the products contain chemicals that could contribute to tropospheric ozone production (Table 5.4). However, the data for the non-MDI-based alternative formulations on this parameter are not certain. The unreacted MDI in the Priority Products is currently classified under the Clean Air Act as such (US EPA, 2018a), but based on their own research, the REs do not consider MDI to be a VOC that contributes to ozone and smog formation. In California, CARB exempts low-vapor pressure VOCs from the California VOC regulations, such as those with a vapor pressure less than 0.1 mm Hg at 20°C or a boiling point greater than 216°C (CARB, 2020). Therefore, MDI is considered a low-vapor-pressure VOC with negligible potential to contribute to tropospheric ozone production due to MDI's vapor pressure of 0.000021 mg Hg at 25°C (Olf, 2018) and boiling point of >300°C (ECHA, 2020). Additionally, according to Tury *et al.* (2003), unreacted MDI is demonstrated to have low ozone-forming potential and does not contribute to smog formation.

Category	Factor that Is Relevant if Materially Different Between Products[1] (*i.e.*, Priority Products and Alternatives)	Relevant?[2]	Basis
Adverse Ecological Impacts	Would the product, its constituents, or its likely breakdown products have any acute or chronic toxicity to impact aquatic, avian, or terrestrial animal or plant organisms or microbes?	Potentially	As shown in Table 5.4, the Priority Products' functional ingredients do not pose any aquatic toxicity, but there are a few data gaps, particularly on the polyester polyol and the polyols used in BASF Patent No. WO 2019/089237 A1 (Wishneski *et al*., 2019). Conversely, several functional ingredients in the non-MDI-based patents pose acute and chronic aquatic toxicity hazards (Table 5.4). No data were located on hazards to avian, plant, or microbial receptors. However, at least one functional ingredient in the Priority Products and one of the alternatives poses terrestrial toxicity (Table 5.4). Similarly, the main transformation products of some Priority Products and alternatives pose acute and aquatic toxicity (Table 5.5). With that said, exposure of ecological receptors is unlikely due to the product use and disposal patterns of SPF. SPF insulation products are not used in a manner that would lead to ecological effects unless there are accidental spills or leaks, or they are improperly disposed of. They are used inside structures or on top of roofs, not washed into stormwater or surface water, not used on the land surface, *etc*.

Category	Factor that Is Relevant if Materially Different Between Products[1] (*i.e.*, Priority Products and Alternatives)	Relevant?[2]	Basis
Adverse Ecological Impacts	Would the product bring changes in population size, reduction in biodiversity, or changes in ecological communities?	No	Ecological exposures are unlikely, because SPF is not used in a manner that would lead to ecological emissions or effects unless there are accidental spills or leaks, or they are improperly disposed of. SPF is used inside structures or on top of roofs, not washed into stormwater or surface water, not used on the land surface, *etc*. MDI is highly reactive with water, resulting in an insoluble and inert solid (polyurea) (ECHA, 2020), such that water must be strictly excluded during the production, packaging, storage, and cleaning of SPF formulations or equipment. However, no information is available on other SPF ingredients or non-MDI-based alternative formulations' ingredients on these parameters.
	Would the product bring changes to the abilities of an endangered or threatened species to survive or reproduce?		
	Would the product bring changes to deterioration or the loss of environmentally sensitive habitats?		
	Would the product bring changes that contribute to or cause vegetation contamination or damage?		
	Would it bring adverse effects on environments that have been designated as impaired by a California State of federal regulatory agency?		
	Would it result in biological or chemical contamination of soils?	Potentially	According to manufacturer recommendations and applicable laws, unused unreacted SPF would not be released into the environment (see Section 4.6.11). In the event of accidental spills, leaks, and improper disposal, the Priority Products and non-MDI-based alternative formulations differ in the K_{oc} values of their ingredients, which could be a relevant factor in exposure to soil, sediment, and groundwater (Table 5.12).

Category	Factor that Is Relevant if Materially Different Between Products[1] (*i.e.*, Priority Products and Alternatives)	Relevant?[2]	Basis
Adverse Ecological Impacts	Any other adverse effects, as defined in Section 69401.2(a) (CalDTSC, 2012a), for environmental hazard traits and endpoints specified in Article 4 of Chapter 54, as follows: • Domesticated animal toxicity • Eutrophication • Impairment of waste management organisms • Loss of genetic diversity (including biodiversity) • Phytotoxicity • Wildlife developmental impairment • Wildlife growth impairment • Wildlife reproductive impairment • Wildlife survival impairment Evidence for environmental hazard traits (*i.e.*, from standard aquatic and terrestrial toxicity testing, research-based investigations, mechanistic evidence from cell-based or whole organism-based assays showing perturbations of known physiological, biochemical or other pathways, or evidence from quantitative structure activity relationship programs).	Potentially	As shown in Table 5.4, the Priority Products' functional ingredients do not pose any aquatic toxicity, but there are a few data gaps, particularly on the polyester polyol and the polyols used in BASF Patent No. WO 2019/089237 A1 (Wishneski *et al*., 2019). Conversely, several functional ingredients in the non-MDI-based alternative formulation patents pose acute and chronic aquatic hazards (Table 5.4). No data were located on potential impact to domesticated animals, eutrophication, waste management organisms, loss of genetic diversity, phytotoxicity, or wildlife. However, at least one functional ingredient in the Priority Products and in one of the alternatives poses terrestrial toxicity (Table 5.4). Similarly, the main transformation products of some Priority Products and alternatives pose acute and chronic aquatic toxicity (Table 5.5).
Adverse Soil Quality Impacts	Would the product impact soil compaction or other soil structure changes?	No	SPF insulation products are not used in a manner that would lead to effects on these soil characteristics. However, no information on soil structure, erosion, loss of organic matter, or soil sealing was found for the Priority Products and non-MDI-based alternative formulations. Given the use patterns of SPF, such effects are not expected.
	Would the product impact soil erosion?		
	Would the product cause loss of organic matter in soil?		
	Would the product cause soil sealing?		

Category	Factor that Is Relevant if Materially Different Between Products[1] (*i.e.*, Priority Products and Alternatives)	Relevant?[2]	Basis
Adverse Water Quality Impacts	Would the product be expected to directly enter the municipal storm sewer systems (*e.g.*, car wash detergents)?	Unlikely	SPF insulation products are not used in a manner that would lead to entry into sewer systems. The reacted product is a solid. Disposal of cured SPF at the end-of-life phase will be as solid or construction waste (Section 4.6.11). According to manufacturer recommendations and applicable laws, unused unreacted SPF would not be released into the environment (see Section 4.6.11). In the event of a spill, according to industry guidance, absorbent materials such as pads, sand, or cat litter are recommended to contain the affected area in the event of a MDI spill while wearing personal protective equipment (PPE) (ACC, 2020). In the unlikely event that MDI enters the waterway due to an accidental spill or leak *that has not been contained*, the insoluble polyurea could potentially clog a small-diameter drain, especially if the spill is not accompanied by flowing water. Typically, the polyurea would not occupy more than twice the volume of the originally spilled material (Yakabe *et al*., 1999). There are no data indicating that these products, if improperly disposed of in this way, would significantly affect biological or chemical oxygen demand. Lastly, MDI in water does not result in an exothermic reaction; thus, any accidental spill or leak should not increase the temperature of the water systems (Bailey *et al*., 2003).
	Would the product bring any increase in biological oxygen demand within the water system?	No	
	Would the product bring any increase in chemical oxygen demand within the water system?		
	Would the product bring any increase in the temperature of water systems?		
	Would the product bring any increase in total dissolved solids in water systems?		
	Increase in California CWA priority pollutants	Yes	Based on a review of the California Clean Water Act (CWA) Hazardous Substances, Priority Pollutants, and Toxic Pollutants lists (UL LLC, 2020), and to the best of our knowledge, none of the products contain functional ingredients present on these lists. However, a potential transformation product of BPA (a functional ingredient in the Owens Corning formulation [Olang, 2012]) is phenol, which is present on all three of these lists.
	Increase in California CWA pollutants		

Category	Factor that Is Relevant if Materially Different Between Products[1] (*i.e.*, Priority Products and Alternatives)	Relevant?[2]	Basis
Adverse Water Quality Impacts	Increase in chemicals with drinking water MCLs	No	Based on a review of the relevant regulations (22 CCR § 64431, § 64444, and § 64449) and to the best of our knowledge, none of the products contain functional ingredients that have drinking water MCLs. The same applies to the main transformation products of the functional ingredients.
	Increase in chemicals with drinking water notification levels	No	Based on a review of the California guidance (CalSWRCB, 2020) and to the best of our knowledge, none of the products contain functional ingredients that have drinking water notification levels. The same applies to the main transformation products of the functional ingredients. Note that 1,4-dioxane, which has a notification level, is not an ingredient in SPF, as suggested by the US EPA's TSCA risk evaluation of 1,4-dioxane (US EPA, 2019a).
	Increase in chemicals with drinking water public health goals	No	Based on a review of the relevant regulation (CalOEHHA, 2019b) and to the best of our knowledge, none of the products contain functional ingredients that have drinking water public health goals. The same applies to the main transformation products of the functional ingredients.
	Exceedance of a standard relating to the protection of the environment	No	To the best of our knowledge, use of the Priority Products or the non-MDI-based alternative formulations will not require intentional exceedance of such a standard.
Public Health Impacts	Acute mammalian toxicity	Yes	Among the functional ingredients we assessed, many of the products contain chemicals with this property (Table 5.2).
	Carcinogenicity	Yes	Among the functional ingredients we assessed, some of the products contain chemicals with this property (Table 5.2).
	Developmental toxicity	Yes	Among the functional ingredients we assessed, only the Owens Corning formulation contain chemicals with this property (Olang, 2012; Table 5.2).
	Reproductive toxicity		
	Cardiovascular toxicity	Yes	Among the functional ingredients we assessed, some non-MDI-based alternative formulations contain chemicals with this property (Table 5.3).
	Dermatotoxicity	Yes	Among the functional ingredients we assessed, most of the products contain chemicals with this property (irritancy) (Table 5.2).

Category	Factor that Is Relevant if Materially Different Between Products[1] (*i.e.*, Priority Products and Alternatives)	Relevant?[2]	Basis
Public Health Impacts	Eye irritation	Yes	Among the functional ingredients we assessed, most of the products contain chemicals with this property (Table 5.2).
	Respiratory sensitization	No	Among the functional ingredients we assessed, all of the products contain chemicals with one or both of these properties (Table 5.2), and thus, there is no material difference in this parameter between the Priority Products and potential alternatives.
	Skin sensitization		
	Organ toxicity	Yes	Among the functional ingredients we assessed, most of the products contain chemicals with this property. The severity also differs among the products (Table 5.2).
	Endocrine toxicity	Yes	Among the functional ingredients we assessed, some of the non-MDI-based alternative formulations contain chemicals with this property (Table 5.2).
	Epigenetic toxicity	No	Epigenetic toxicity refers to the ability to alter gene expression without necessarily changing gene structure. We considered whether chemicals were reported to be genotoxic as an indication of an ability to interact with DNA. All of the functional ingredients evaluated were either found to be not genotoxic or had data gaps relating to genotoxicity. We found no reports of typical epigenetic mechanisms (*i.e.*, DNA methylation) for any of the functional ingredients evaluated in the data sources consulted; however, a material difference between the Priority Products and the alternatives is not expected for this parameter (as summarized in Table 5.3).
	Genotoxicity/mutagenicity	Yes	Among the functional ingredients we assessed, two of the non-MDI-based alternative formulations contain a chemical with this property (Table 5.2).
	Hematotoxicity	Yes	Among the functional ingredients we assessed, some of the products contains a chemical with this property (Table 5.3).
	Hepatotoxicity and digestive system toxicity	Yes	Among the functional ingredients we assessed, most of the products contain chemicals with this property (Table 5.3).

Category	Factor that Is Relevant if Materially Different Between Products[1] (*i.e.*, Priority Products and Alternatives)	Relevant?[2]	Basis
Public Health Impacts	Immunotoxicity	No	Among the functional ingredients we assessed, all the products contain chemicals with this property (Table 5.3). Some products contain both respiratory and dermal sensitizers, whereas other only contain a chemical with one of these properties.
	Musculoskeletal toxicity	No	Among the functional ingredients we assessed, none of the products contain chemicals with this property (Table 5.3).
	Nephrotoxicity	Yes	Among the functional ingredients we assessed, some of the products contain chemicals with this property (Table 5.3).
	Neurodevelopmental toxicity	Yes	Among the functional ingredients we assessed, some of the products contain a chemical with these properties (Table 5.3).
	Neurotoxicity		
	Ototoxicity	No	Among the functional ingredients we assessed, only one had data on this endpoint (no adverse effects were observed) (Table 5.3). All other functional ingredients had data gaps for this endpoint (*i.e.*, the studies reviewed did not indicate an evaluation was conducted for ototoxicity) (Table 5.3).
	Reactivity in biological systems[4]	Unclear	More information on this criterion is needed to evaluate this endpoint. All chemicals are reactive in biological systems to some extent.
	Respiratory toxicity	Yes	Among the functional ingredients we assessed, most of the products contain chemicals with these properties (Table 5.3).
	Exceedance of an enforceable California or federal standard related to public health	No	To the best of our knowledge, use of the Priority Products or non-MDI-based alternative formulations will not require intentional exceedance of such a standard, other than the ones already addressed elsewhere in this table.

Category	Factor that Is Relevant if Materially Different Between Products[1] (*i.e.*, Priority Products and Alternatives)	Relevant?[2]	Basis
Waste and End-of-Life Effects	Would the product bring any change to the volume or mass of the waste materials and byproducts generated during the life cycle?	Unlikely, but data are limited	All the products, once cured, would be disposed of as solid or construction waste at the end-of-life phase. There is no expectation that any of the non-MDI-based alternative formulations would generate more production waste or application waste than the Priority Products, although details on these aspects are scarce because the alternatives are not commercialized. The lower-exposure approaches, which are MDI-based, would be similar. No information related to special handling or treatment needs was identified in the patents reviewed.
	Would the product need any special handling to mitigate adverse impacts resulting from the waste materials generated during the life cycle?	No	
	Effects on solid waste or wastewater disposal or treatment		
	Effects on discharge(s) or disposal(s) to storm drains or sewers adversely affecting wastewater or storm water treatment facilities	No	SPF insulation products are very unlikely to be disposed of *via* stormwater/wastewater systems. The products are intended to be resistant to dissolution in water but pose no special blockage hazards not associated with other solid waste materials.
	Release to the environment	No	All SPF insulation products can be expected to be manufactured, used, and disposed of similarly or *via* analogous processes. A material difference between the Priority Products and any alternatives in terms of environmental release potential is not expected.
Environmental Fate	Aerobic and anaerobic half-lives of the product, its constituents, or its likely breakdown products	Yes	SPF insulation products are unlikely to be discharged to soil, surface water, or groundwater. However, in the unlikely event of a spill or improper disposal of the unreacted SPF or unreacted ingredients in the non-MDI-based alternative formulations, there are differences in the environmental half-life in air (Table 5.12) and biodegradation in water (Table 5.4) of the functional ingredients.
	Aqueous hydrolysis half-life of the product, its constituents, or its likely breakdown products	Yes	One of the non-MDI-based alternative formulations (Dow Patent No. WO 2015/142564 A1 [Foley *et al*., 2015]) describes a water-soluble spray foam. The rest of the cured products are intended to be resistant to dissolution in water. Additionally, there are differences in the water solubilities of the functional ingredients among the products (Table 5.12).

Category	Factor that Is Relevant if Materially Different Between Products[1] (*i.e.*, Priority Products and Alternatives)	Relevant?[2]	Basis
Environmental Fate	Atmospheric oxidation rate	Yes	Among the functional ingredients we assessed, there are differences in the atmospheric lifetime of different chemicals between the Priority Products and non-MDI-based alternative formulations. This is captured by environmental half-life in air (Table 5.12), which is primarily governed by indirect photolysis with photochemically generated hydroxyl radicals. Most of the products contain functional ingredients that have moderate environmental half-lives (between 2 hours and 1 day). However, one product contains a functional ingredient that has a slow environmental half-life (between 1 and 10 days) (Table 12).
	Bioaccumulation of the product, its constituents, or its likely breakdown products	Yes	Among the functional ingredients we assessed, none of the products contain chemicals that are bioaccumulative. However, some of the products contain transformation products that are bioaccumulative, according to their log K_{ow} (Table 5.5).
	Mobility in environmental media	Yes	The Priority Products and non-MDI-based alternative formulations contain chemicals with different properties related to environmental mobility (*e.g.*, vapor pressure relating to exposure to air, log K_{oc} relating to soil adsorption, water solubility relating to exposure to water) (Table 5.12). Some transformation products have different exposure potentials in air, water, soil, and sediments (Table 5.5).
	Persistence	Yes	Among the functional ingredients we assessed, some of the products contain chemicals that are persistent in the environment (Table 5.4). One of the transformation products of MDI (*i.e.,* polyurea) is also persistent in water (Table 5.4).

Category	Factor that Is Relevant if Materially Different Between Products[1] (*i.e.*, Priority Products and Alternatives)	Relevant?[2]	Basis
Environmental Fate	Photodegradation	Yes	According to US EPA's interpretation guidance (US EPA, 2013), there are differences in the atmospheric lifetime, captured by environmental half-life in air, among the Priority Products and non-MDI-based alternative formulations. Most of the products contain functional ingredients that have moderate environmental half-lives (between 2 hours and 1 day). However, one product contains a functional ingredient that has a long environmental half-life (between 1 and 10 days). See Table 5.12 for more details. No information was found for any of the functional ingredients regarding photodegradation in water.
Materials and Resource Consumption	Impacts on consumption of renewable resources, including energy and raw materials, throughout the product life cycle	Unclear	Some SPF insulation products (including some variants of the Priority Products) and one of the non-MDI-based alternative formulations use renewable materials. All other materials appear to be fossil-fuel-derived (Tables 4.3-4.5). No data are available concerning the non-MDI-based formulations, so the material relevance cannot be determined.
	Impacts on consumption of non-renewable resources, including petroleum, coal, metals, minerals, and other finite resources, throughout the product life cycle	Unclear	Some SPF insulation products (including some variants of the Priority Product) and one of the non-MDI-based alternative formulations use renewable materials. All other ingredients appear to be fossil-fuel derived (Tables 4.3-4.5). The thinkstep LCA of SPF indicated that the use of diesel fuel for power generation during SPF installation was a significant life cycle aspect (thinkstep, 2018). This would not be expected to be different for the possible alternatives, although that is not known with certainty for the non-MDI-based alternative formulations. However, lacking a corresponding LCA for the alternatives, it is not possible to quantify other material requirements (*e.g.*, energy inputs, water impacts). Thus, the material relevance of this factor cannot be determined.

Category	Factor that Is Relevant if Materially Different Between Products[1] (*i.e.*, Priority Products and Alternatives)	Relevant?[2]	Basis
Physicochemical Hazards	Do the product or the alternatives exhibit oxidizing properties that facilitate combustion?	No	Based on the ECHA REACH dossiers of the chemicals in the available product compositions, none of the products exhibit this property (ECHA, 2020).
	Do the product or the alternatives exhibit explosivity?	No	Based on the ECHA REACH dossiers of the chemicals in the available product compositions, none of the products exhibit this property (ECHA, 2020).
	Do the product or the alternatives exhibit flammability?	No	None of the functional ingredients we assessed exhibit this property (see Table 5.4 and ECHA, 2020). In addition, most of the products contain flame retardants to suppress inherent flammability.
Physicochemical Properties	Do the product and alternatives have different physical states?	No	The individual ingredients can exist as liquid, semi-liquid, or solid forms but are all applied as a liquid under pressure, so this is not a material difference between the Priority Products and the non-MDI-based alternative formulations. SPF products are not formulated with MDI as a discrete ingredient. Rather, SPF products use pMDI. See Section 3.2 for more details. Note that pure MDI (the chemical of concern) is a solid at room temperature, but pMDI is a viscous liquid at room temperature (ACC, 2012). See Table 5.12 for ingredient physical states.
	Molecular weight	Unlikely	The molecular weights of the functional ingredients vary because some alternatives do not have polymers as the functional ingredients (Table 5.12); however, it seems unlikely that this will make a material difference between the different products except in areas captured better by other parameters (*e.g.*, molecular weight may affect volatility, but this is better captured by vapor pressure).
	Density	Unlikely	Density does vary among the functional ingredients of the products; however, it seems unlikely that this will make a material difference between the different products except in areas captured better by other parameters (*e.g.*, density may affect environmental transport, but water solubility is more critical in this regard).

Category	Factor that Is Relevant if Materially Different Between Products[1] (*i.e.*, Priority Products and Alternatives)	Relevant?[2]	Basis
Physicochemical Properties	Vapor pressure	Yes	The Priority Products and non-MDI-based alternative formulations differ in the vapor pressures of their functional ingredients, which could be a relevant factor for differentiating exposure potential (Table 5.12).
	Melting point	No	Melting point is not relevant because the products are already liquids at feasible use conditions. Boiling point is not relevant because the product is not heated to boiling, and volatility is addressed *via* vapor pressure. The values for both of these parameters for the functional ingredients assessed are reported in Table 5.12.
	Boiling point		
	Water solubility	Yes	The Priority Products and non-MDI-based alternative formulations differ in the water solubility of their functional ingredients (Table 5.12); however, they are not likely to impact water resources as part of their normal use. If introduced into environmental media as a result of an accidental spill or leak, water solubility could be significant in determining environmental dispersion.
	Lipid solubility	Yes	The Priority Products and non-MDI-based alternative formulations differ in the lipid solubility of their functional ingredients. See log K_{ow} in Table 5.12.
	Octanol-water partition coefficient (log K_{ow})	Yes	The Priority Products and non-MDI-based alternative formulations differ in the log K_{ow} of their functional ingredients (Table 5.12), which could be a relevant factor for differentiating exposure potential and mobility in the environment.
	Octanol-air partition coefficient (K_{oa})	No	Partitioning between lipid-like materials and air should not be significant given how SPF insulation products are used. However, K_{oa} values for the functional ingredients assessed are reported in Table 5.12.
	Organic carbon partition coefficient (K_{oc})	Yes	In the event of accidental spills, leaks, and improper disposal, the Priority Products and non-MDI-based alternative formulations differ in the K_{oc} values of their functional ingredients, which could be a relevant factor in exposure to soil, sediment, and groundwater (Table 5.12). However, entry into soil and sediment is unlikely under normal conditions.

Category	Factor that Is Relevant if Materially Different Between Products[1] (*i.e.*, Priority Products and Alternatives)	Relevant?[2]	Basis
Physicochemical Properties	Diffusivity in air and water	Unclear	No data exist for water diffusivity for any of the products' ingredients other than MDI. Diffusivity in air does not apply, because none of the functional ingredients are gases or vapors.
	Henry's Law constant	No	While Henry's Law constants do vary between the Priority Products' and alternatives' functional ingredients, this parameter describes the diffusion of chemicals from water to air and is not relevant for SPF products.
	Sorption coefficient for soil and sediment	Yes	See K_{oc} section above.
	Redox potential	No	No data available.
	Photolysis rates	Yes	No data on the photolysis rates of the products' ingredients were identified, other than for MDI. However, the functional ingredients we assessed have different environmental half-lives in air. Most of the products contain functional ingredients that have moderate environmental half-lives (between 2 hours and 1 day). However, one product contains a functional ingredient that has a long environmental half-life (between 1 and 10 days). See Table 5.12 for more details.
	Hydrolysis rates	Unclear	MDI is readily hydrolyzed in water, and thus is not in itself persistent in the environment. However, no data are available for hydrolysis rates of the products' ingredients other than MDI.
	Dissociation constants		
	Reactivity, including electrophilicity	No	The products are all chemically reactive as part of their function. To perform adequately, they must be chemically reactive, so this is not expected to be materially different among the products.

Category	Factor that Is Relevant if Materially Different Between Products[1] (*i.e.*, Priority Products and Alternatives)	Relevant?[2]	Basis
Product Function and Performance	Are there material differences in terms of the useful life of the product?	Yes	The available product performance information for the potential alternatives is inadequate. None of the patents contain a complete set of required product performance criteria (Table 5.10). The useful life of the cured SPF product is 75 years (Section 4.6.8); however, no comparable information is available for the non-MDI-based alternative formulations. The shelf lives of the alternative ingredients are unknown as well. Components that are used outside of their shelf life will result in foam that does not meet code requirements and could pose a safety hazard in the supply chain, as well as to the user themselves. Any alternative must have a shelf life that is at least as long as current commercial products (>12 months) in order to meet customer/ market expectations and be commercially viable, according to one RE. In particular, the shelf-life of components described in Patent No. WO 2013/101682 A1 (Jin *et al.*, 2013) was unacceptable (<2 months), according to communications with DuPont. As shown in Table 5.10, there are differences in terms of the relative performance of the products that pertain to the issue of technical feasibility.
	Are there material differences in terms of the function and performance of the product?		
	Are there material differences in terms of the functional acceptability of the product?		
	Are there material differences in terms of the technical feasibility of the product?		
Economic Impacts	Will the product and its alternatives have a different cost to consumers or other users?	Potentially	Most of the potential alternatives are not commercially available; thus, the cost of the alternatives is not known. Those that are commercially available are not expected to be substantially different in cost from the Priority Products.

Notes:
BPA = Bisphenol A; CalDTSC = California Department of Toxic Substances Control; CARB = California Air Resources Board; ECHA = European Chemicals Agency; HFC = Hydrofluorocarbon; HFO = Hydrofluoroolefin; LCA = Life Cycle Assessment; MCL = Maximum Contaminant Level; MDI = Methylene Diphenyl Diisocyanate; pMDI = Polymeric Methylene Diphenyl Diisocyanate; RE = Responsible Entity; REACH = Registration, Evaluation, Authorisation, and Restriction of Chemicals; SPF = Spray Polyurethane Foam; TSCA = Toxic Substances Control Act; US EPA = United Sates Environmental Protection Agency; VOC = Volatile Organic Compound.
Safer Consumer Products (SCP) regulations: CalDTSC (2013) (22 CCR § 69505.5).
(1) The term "product" is used in this column to refer to the Priority Products and the possible alternatives.
(2) The response "No" under relevant factor indicates either that data exist to indicate the factor is not relevant or that there are no data available.
(3) US EPA (2018b).
(4) Any chemical can be reactive in biological systems (*e.g.*, water, oxygen). We interpret this to mean reactivity in some way not captured by the other health-related factors and having an effect that is harmful.

Table 4.2 Life Cycle Elements Considered in Evaluating Potential Exposures

Category	Element	Relevant?[1]	Basis
Chemical Quantity Information	Would the alternative change the quantities of the chemical(s) of concern or other replacement chemicals necessary to manufacture the product?	No	Based on available information from patents, the amount of functional ingredients is not expected to be materially different between the Priority Products and the non-MDI-based alternative formulations.
	Would the alternative change the quantities of the chemical(s) of concern or other replacement chemicals placed into the stream of commerce in California?		
Market Presence of Product	Would the alternative change statewide sales of the product by volume?	Unclear	Ways in which the volume could change would be if an alternative provided greater (or lesser) effectiveness (*e.g.*, insulation) at a smaller volume or if an alternative was more costly, such that it had less use. Data with which to assess these possibilities for many of the alternatives are unavailable.
	Would the alternative change statewide sales of the product by number of units?		
	Would the alternative change the intended product use(s), and types and age groups of targeted customer base(s)?	No	The Priority Products are defined by their use, and so any replacement product would have to be available for the same use.
Occurrence or Potential Occurrence of Exposure	Will there be a difference in occurrence or potential occurrence of exposure to Candidate Chemicals in the product?	Yes	Some non-MDI-based alternative formulations also contain candidate chemicals, while others do not, although information on the final formulations for these alternative formulations is lacking. See Sections 4.3.1 and 4.3.2 for more details.
Household and Workplace Presence	Will the product be used in the home?	Yes	The high-pressure Priority Products are sold to professionals, whereas low-pressure Priority Products can be sold to non-professional DIY applicators, who may use the products at home as air sealants and for small-scale infrequent insulation applications. While none of the non-MDI-based alternative formulations are commercially available, we can assume that any safer alternative will be used in homes by professionals and/or DIY applicators.
	Will the product be used in the workplace?	Yes	Potentially, in commercial buildings. Also, installation in homes can be considered as occurring in a temporary workplace.

Category	Element	Relevant?[1]	Basis
Potential Exposure	Are there differences in the manufacturing, use, storage, transportation, waste, or end-of-life management of the product and alternatives?	Yes (for some life cycle stages; refer to Section 4.6)	There are likely differences in exposure potential during use/ application among the products, although it is likely that applicators will continue to wear PPE for the use of high-pressure equipment. The effects on other life cycle stages are discussed in Section 4.6.
	Is the product manufactured, stored, or transported through California but not used in California?	No	The product is used in California.
	Is the product an intermediate product used to manufacture an exempted product?	No	The product is not an intermediate.
	Does the product have household use?	Yes	See above (Household and Workplace Presence).
	Does the product have recreational use?	No	This product is not for recreational use.
	Are there sensitive subpopulations that use the product and alternatives?	Yes	Sensitive populations include workers, sensitized individuals, children, the elderly, and pregnant women. None of these populations, except workers, are likely to be users of the Priority Products.
	Is the product used in homes?	Yes	See above (Household and Workplace Presence).
	Is the product used in schools?	Yes	The product could potentially be used in schools by workers, but not by students or teachers, and should not be applied when these bystanders are present.
	Is the product used in workplaces?	Yes	See above (Household and Workplace Presence).
	Is the product used in other unusual locations?	No	None are known to the REs involved in this Abridged AA.
	Is there a difference in the frequency, extent, level, and duration of exposure potential for the product and its alternatives during use?	Potentially	Performance data for the alternatives are generally lacking, so it is unclear if any of them could be applied in the same timeframe as the Priority Products.
	Is there a difference in the frequency, extent, level, and duration of exposure potential for the product and its alternatives at end-of-life?	Unlikely for lower-exposure approaches; Unclear for non-MDI-based alternative formulations	Products should all be disposed of *via* the same process. All cured products would presumably be managed as non-hazardous waste. However, there would be different exposure potential for the unreacted ingredients if spilled, leaked, or improperly disposed of.

Category	Element	Relevant?[1]	Basis
Potential Exposure	Is there a difference in how the candidate chemical is contained within the product and its alternatives?	No	All products are part of a multi-chemical liquid blend prior to application and then an inert solid after application.
	Is there a difference in terms of engineering and administrative controls to reduce exposure among the product and its alternatives?	Yes	All products would be governed by the same occupational or consumer product regulations. Some alternatives use engineering controls (*e.g.*, Firestone/Gaco Profill System) to reduce exposure.
	Is there a difference in the potential of the candidate chemical and degradation products to release into, accumulate in, and persist in the environment?	Potentially	While data are not available for every functional ingredient assessed, a material difference is assumed. MDI itself is not persistent or bioaccumulative, but some of the ingredients in the Priority Products and the possible alternatives (polymers) are persistent but not bioaccumulative. Some alternatives have functional ingredients that do not appear to be persistent (*e.g.*, Firestone/Gaco Profill System™), although data are lacking for some chemicals. Polyurea, an environmental product of MDI, is persistent. Data are lacking in this regard for some of the functional ingredients of the possible alternatives.

Notes:

DIY = Do-it-Yourself; pMDI Polymeric Methylene Diphenyl Diisocyanate; PPE = Personal Protective Equipment; RE = Responsible Entity; SPF = Spray Polyurethane Foam.

(1) The response "No" under relevant element indicates either that data exist to indicate that the element is not relevant or that there are no data available.

5 Comparison of Alternatives

5.1 Hazard

Gradient collected information on the ingredients of the potential alternative formulations and lower-exposure approaches from their respective patents and SDSs, if available, except in the case of NanoSonic HybridSil, for which no ingredient information or patent could be located. When chemical information was lacking for products for which the producer/patent holder was an RE, we sought additional information on product's ingredients. An evaluation of the potential alternatives identified revealed similar B-side compositions, other than the functional ingredients of the non-MDI-based alterative formulations, compared to those of the Priority Products (*i.e.*, similar flame retardants, blowing agents, surfactants, *etc.*) (see Table 5.1). Because the listing for the Priority Products is based on the fact that the A-side contains MDI (a functional ingredient), less focus was given to non-functional ingredients, such as flame retardants, which would be expected to have similar hazards across the potential alternatives. Because the functional ingredients, *i.e.*, those that make up the polyurethane or equivalent polymer backbone, of the two "sides" of each product differ from one another, we more thoroughly evaluated the hazards and other properties of these functional ingredients. For the Priority Products, this meant MDI/pMDI and the polyols with which it reacts. For some of the non-MDI-based alternative formulations, it meant the corresponding ingredients that served the same functional role. These chemicals are identified in Table 5.1.

Table 5.1 Comparison of Components for Priority Products (Generic Formulae) and Identified Alternatives

Product	Group Type	Components	Function	% of Product	Sources
Generic MDI-based Formulations[1]					
Priority Product (Generic Formula)	Group 1: Low Pressure (Various Densities)	pMDI (Monomeric and Oligomers)	Functional ingredient	46.25	Wood (2014)
		Polyester Polyol	Functional ingredient	11.50	
		Polyether Polyol	Functional ingredient	11.50	
		HFC-134a[2]	Blowing agent	12.25	
		tris-(1-Chloro-2-propyl) Phosphate	Flame retardant	15.00	
		Silicone Surfactant	Surfactant	1.00	
		Pentamethyldiethylene Triamine	Amine catalyst	2.50	
Priority Product (Generic Formula)	Group 2: High Pressure, Low Density, Open Cell, 0.5 lb/f[3]	pMDI (Monomeric and Oligomers)	Functional ingredient	50.00	Wood (2014)
		Polyether Polyol	Functional ingredient	17.00	
		Water	Blowing agent	10.00	
		tris-(1-Chloro-2-propyl) Phosphate	Flame retardant	12.60	
		Nonylphenyl Ethoxylated	Emulsifier	5.95	
		Silicone Surfactant	Surfactant	0.50	
		bis (2-Dimethylaminoethyl) Ether (BDMAEE)	Amine catalyst	0.45	
		Tetramethyliminobispropylamine (TMIBPA)	Amine catalyst	1.50	
		N,N,N-Trimethylamino Ethylethanolamine (TMAEEA)	Amine catalyst	2.00	
Priority Product (Generic Formula)	Group 3: High Pressure, Medium Density, Closed Cell, 2 lbs/f[3]	pMDI (Monomeric and Oligomers)	Functional ingredient	50.00	Wood (2014)
		Aromatic Polyester Polyol	Functional ingredient	18.20	
		Aromatic Amino Polyether Polyol	Functional ingredient	16.81	
		HFC-245fa[2]	Blowing agent	3.49	
		Water	Blowing agent	1.27	
		Tris-(1-Chloro-2-propyl) Phosphate	Flame retardant	7.96	
		Silicone Surfactant	Surfactant	0.50	
		bis (2-Dimethylaminoethyl) Ether (BDMAEE)	Amine catalyst	0.35	
		bis (Dimethylaminopropyl) Methylamine (DAPA)	Amine catalyst	1.30	
		N,N,N-Trimethylamino Ethylethanolamine (TMAEEA)	Amine catalyst	0.15	

Product	Group Type	Components	Function	% of Product	Sources
Non-MDI-based Alternative Formulations					
Firestone/Gaco Canary™ Example Formulation	Group 3 and/or 4. Not enough information to assign definitively.	Acetoacetylated Sucrose	Functional ingredient	26.09	Trumbo *et al*. (2016)
		Acetoacetylated Glycerin	Functional ingredient	26.09	
		Meta Xylene Diamine (MXDA)	Functional ingredient; Amine	15.48	
		Dytek® A (2-Methyl-1,5-diaminopentane)	Functional ingredient; Amine	10.26	
		Dimethylbis([1-oxoneodecyl] oxy)stannane	Metal catalyst	1.55	
		Tegostab™ B-8407	Surfactant (silicone based)	0.83	
		Tegostab™ B-8221	Surfactant (silicone based)	0.52	
		tris-(1-Chloro-2-propyl) Phosphate	Flame retardant	16.05	
		HFC-365mfc	Blowing agent	3.13	
Hybrid Coatings Technologies/ Nanotech Industries Green Polyurethane™ Example Formulation	Group 3, and/or 4. High Pressure, Closed Cell (but not enough information to assign definitively).	DER 331, a BPA Epoxy Resin	Functional ingredient	81.80	NanoSonic Inc. (2012); Figovsky *et al*. (2015)
		Ancamine 2678	Functional ingredient; Amine	14.30	
		DC-1107	Surfactant (silicone based)	1.30	
		DC-197	Surfactant (silicone based)	5.20	
		Undisclosed Blowing Agent	Blowing agent	No Data	
		Presumed Flame Retardant (not discussed in patent but presumably required)[3]	Flame retardant	No Data	
Owens Corning Example Formulation	Group 2, 3, and/or 4. Not enough information to assign definitively.	DER 331, a BPA Epoxy resin	Functional ingredient	45.73	Olang (2012)
		Epon™ 8111, an Epoxy Resin	Functional ingredient	16.34	
		Cycloate A/Ancamine 2678	Functional ingredient; Amine	17.49	
		Epikure™ 3271	Functional ingredient; Amine	4.08	
		Sodium Hydroxide	Misc. additive	0.65	
		DC193	Surfactant (silicone based)	5.07	
		Dye	Dye	0.09	
		Undisclosed Blowing Agent	Blowing agent	No Data	
		Undisclosed Flame Retardant	Flame retardant	No Data	

Product	Group Type	Components	Function	% of Product	Sources
DuPont Patent No. WO 2013/101682 A1 Example Formulation	Group 2, 3, and/or 4. Not enough information to assign definitively.	Tetrafunctional Acrylate	Functional ingredient	30.04	Jin *et al*. (2013)
		Difunctional Acrylate A, a BPA Epoxy Diacrylate	Functional ingredient	10.94	
		Trimethylolpropane tris(Acetoacetonate)	Functional ingredient	32.26	
		N,N,N',N'-Tetramethylguanidine (TMG)	Amine catalyst	2.21	
		tris(2-Chloropropyl)phosphate	Flame retardant	2.09	
		Triethyl Phosphate	Flame retardant	0.43	
		Tegostab™ B8469	Surfactant (silicone based)	1.70	
		HFC-245fa	Blowing agent	3.16	
		HFC-134a	Blowing agent	17.03	
DuPont Patent No. WO 2018/005142 A1 Example Formulation	Group 2, 3, and/or 4; Not enough information to assign definitively.	Polycarbamate 2	Functional ingredient	~31.60	Thomas *et al*. (2018)
		1,3- and 1,4-Cyclohexane Dicarboxaldehyde (CHDA)	Functional ingredient	~36.41	
		Tetrabromo Phthalate Diol	Flame retardant	~1.98	
		Triethyl Phosphate	Flame retardant	~4.46	
		Silicone Polyether Copolymer Surfactant	Surfactant (silicone based)	Insufficient Data	
		p-Toluenesulfonic Acid	Catalyst	~1.45	
		Magnesium Oxide	Misc. additive	~4.27	
		HFC-245fa	Blowing agent	~19.83	
Dow Patent No. WO 2015/142564 A1 Example Formulation	Group 2, 3, and/or 4. Not enough information to assign definitively.	Polycarbamate	Functional ingredient	45.00	Foley *et al*. (2015)
		1,3- and 1,4-Cyclohexane Dicarboxaldehyde (CHDA)	Functional ingredient	33.50	
		Unspecified Catalyst ("Lewis acids" or "protic acids")	Catalyst	0.50	
		Triethyl Phosphate	Flame retardant	3.60	
		Tetrabromophthalate Diol	Flame retardant	15.10	
		Niax L5340	Surfactant (silicone based)	2.69	

Product	Group Type	Components	Function	% of Product	Sources
Lower-Exposure Approaches (Also Priority Products)					
Firestone/Gaco Profill System™	Group 2: High Pressure, Low Density, Open Cell, 0.5 lb/f3	pMDI (Monomeric and Oligomers)	Functional ingredient	50.00	Gaco Western (2017b, 2020)
		beta-D-Fructofuranosyl alpha-D-Glucopyranoside	Functional ingredient	15.00	
		Nonylphenol polyethylene Glycol Ether	Emulsifier	5.00	
		Dimethylaminoethoxyethanol	Organotin catalyst	2.50	
		2-([2-(2-[Dimethylamino] Ethoxy)ethyl] methylamino)ethanol	Amine catalyst	2.50	
		Unnamed Flame Retardant	Flame retardant	No Data	
		Presumed Surfactant[3]	Surfactant	No Data	
		Water[3]	Blowing agent	No Data	
High-Volume, Low-Pressure Systems (*e.g.,* Nitrosys/ICP HandiFoam® HVLP MD 2.0)	Group 3: High Pressure, Medium Density, Open Cell, 2 lbs/f3	pMDI (Monomeric and Oligomers)	Functional ingredient	50.00	ICP Building Solutions Group (2019a,b)
		Unnamed Polyester Polyol	Functional ingredient	No Data	
		Diethylene Glycol	Functional ingredient	2.50	
		Aromatic Amino Polyether Polyol	Functional ingredient	16.81 (based on generic formula)	
		1,1,1,3,3-Pentafluoropropane	Blowing agent	5.00	
		2-Dimethylaminoethanol	Amine catalyst	1.50	
		Triethyl Phosphate	Flame retardant	7.50	
		2-((2-(Dimethylamino) Ethyl)methylamino) ethanol	Misc. additives	0.15	
		Stoddard Solvent	Misc. additives	0.10	
		2-Ethyhexanoic Acid	Misc. additives	0.10	

Product	Group Type	Components	Function	% of Product	Sources
BASF Patent No. 9592516 B2 Example Formulation	Groups 2 or 3: High Pressure	pMDI (Monomeric and Oligomers)	Functional ingredient	50.00	Wishneski *et al*. (2017)
		Polyethylene Terephthalate, Diethylene Glycol (DEG), Phthalic Acid, and/or Terephthalic Acid	Functional ingredient	22.50	
		Phenol or Nonylphenol, Formaldehyde, and/or Amines, "one or more with propylene oxide and optionally ethylene oxide" (Wishneski *et al*., 2017)	Functional ingredient	12.50	
		Sucrose, Glycerin, Propylene Glycol, and/or Propylene Oxide	Functional ingredient	5.00	
		Tetrabromo Phthalic Anhydride Diol	Flame retardant	5.00	
		tris-(Chloroisopropyl) Phosphate and/or Triethylphosphate	Flame retardant	5.00	
		"Combinations of tertiary amines of varying chemical structure" (Wishneski *et al*., 2017): Dimethylethanolamine (DMEA), Triethylenediamine (TEDA), Pentamethyldiethylenetriamine, and/or 2-{{2-(Dimethylamino) Ethyl}methylamino}-ethanol	Amine catalyst	3.50	
		DABCO DC193	Surfactant	0.50	
		1,1,1,1,1-Pentafluoropropane	Blowing agent	5.00	
		Water	Blowing agent	0.95	

Product	Group Type	Components	Function	% of Product	Sources
BASF Patent No. WO 2019/089237 A1 Example Formulation	Patent contains multiple embodiments of both low- and high-pressure systems (not enough information to assign grouping).	pMDI (Monomeric and Oligomers)	Functional ingredient	50.00	Wishneski *et al*. (2019)
		Aromatic Polyester (*e.g.*, Terol 258)	Functional ingredient	22.56	
		GSP-280 Polyol	Functional ingredient	11.87	
		Tetrabromophthalate Diol	Flame retardant	2.50	
		Triethyl Phosphate	Flame retardant	2.50	
		Tegostab B8453	Surfactant	0.75	
		Dabco 33LV	Amine catalyst	1.25	
		Dabco T	Amine catalyst	0.25	
		Dimethylethanolamine (DMEA)	Amine catalyst	1.25	
		Dabco T120	Organotin catalyst	0.50	
		Ethacure 100 (Diethyltoluenediamine)	Amine	2.50	
		Opteon 1100 (an HFO)	Blowing agent	4.00	
		Water	Blowing agent	0.08	

Notes:
BPA = Bisphenol A; HFC = Hydrofluorocarbon; HFO = Hydrofluoroolefin; HVLP = High Volume Low Pressure; lb = Pound; MDI = Methylene Diphenyl Diisocyanate; pMDI = Polymeric Methylene Diphenyl Diisocyanate; PPE = Personal Protective Equipment; SDS = Safety Data Sheet; SPF = Spray Polyurethane Foam.

Assumptions:
- Assumed pMDI to be 50% of total composition unless stated otherwise.
- Assumed maximum percentage, if a percentage range was given in the patent or SDS (therefore, the combined percentage of components may exceed 100% for some alternatives).
- Composition of the Firestone/Gaco Canary's example formulation was converted from gram to percent weight.
- Composition of the DuPont Patent No. WO 2018/005142 A1 example formulation was converted from mmols to percent weight.

(1) No generic formula exists for Group 4: High Pressure, Closed Cell, 3 lbs/f^3.
(2) High global warming potential HFCs were banned in California in 2020 for high-pressure SPF products and alternatives, and will be banned in 2021 for low-pressure SPF products and alternatives (CARB, 2018a), and products that currently use them are being reformulated to contain lower global warming potential alternatives (*e.g.*, HFOs). However, the patent information pre-dates this ban, so to make comparisons easier, we have not included lower global warming potential blowing agents in this table.
(3) Not listed on SDS, presumably because it does not meet hazard criteria for listing. Presumed to be present because similar products contain such components.

5.1.1 Hazard Evaluation

While the composition of the non-functional ingredients were similar across all the evaluated products, the functional ingredient composition was substantially different for some. See Section 4.3 and Table 5.1 for the alternatives' composition information. Following discussions with CalDTSC, in order to streamline the assessment for this Abridged AA, we compared the functional ingredients of the Priority Products and the possible alternatives to screen for potential hazards.

It is important to stress that while ingredient-specific hazards are presented in this section, ingredient-specific hazards usually do not reflect the hazards of the actual final product when fully cured and installed. For example, MDI is a dermal sensitizer; however, polyurethane (*i.e.*, the reacted foam) is not a dermal sensitizer, even though it was made with MDI. According to Krone and Klinger (2005, as cited in US EPA, 2011), "Completely cured products are fully reacted and therefore are considered to be inert and non-toxic."

Even the product-level hazard of unreacted SPF does not consider the level of exposure, something that must be quantified to calculate and estimate health risk. The California SCP regulations (and AA in general) do not allow REs to incorporate a quantitative estimate of health risk (*i.e.*, combining estimates of dose and exposure to determine the likelihood of an adverse exposure) in making decisions about whether alternatives should be selected (CalDTSC, 2013). However, it is important to note when reviewing chemical hazard data on products that the indication of a high hazard does not necessarily equate to an actual health risk. Risk and hazard are different concepts.

Group A Endpoints

For the Group A hazard endpoints (*e.g.*, dermal sensitization, carcinogenicity, target organ toxicity following repeated exposure), we reviewed the hazard properties of the functional ingredients contained in the Priority Products, non-MDI-based alternative formulations, and lower-exposure approaches for hazard properties using mainly ECHA Registration, Evaluation, Authorisation, and Restriction of Chemicals (REACH) dossiers (ECHA, 2020). The Pharos database (Healthy Building Network, 2020) was consulted in an attempt to fill any data gaps in the ECHA dossier information (Tables 5.2 and 5.4). We prioritized the ECHA dossier conclusions over those of Pharos because the underlying studies and rationale are available in the dossiers, but not in Pharos. Because Pharos classifies hazards as low, moderate, high, and very high, we used the GreenScreen® hazard interpretation guide (Clean Production Action, 2018, Appendix D) to translate Pharos classifications into Globally Harmonized System of Classification and Labelling of Chemicals (GHS) Categories 1, 2, 3, and 4 (UN, 2019), which also align with the ECHA dossier classifications. For example, if an ingredient is classified as a GHS Category 1A respiratory sensitizer, then the ingredient would be considered a "high" respiratory sensitization hazard under GreenScreen® and Pharos. There are also a number of additional hazard concerns required by the SCP regulations that are not classified in the ECHA dossiers. These were addressed as follows:

- **Endocrine Disruption and California Proposition 65.** The European Union's (EU) Endocrine Disruptor Priority List and the California Proposition 65 list were used to inform these endpoints (UL LLC, 2020).
- **Terrestrial Toxicity.** Pharos (Healthy Building Network, 2019) was used to inform this endpoint.
- **Bioaccumulative Potential.** Ingredients are considered not bioaccumulative if the bioconcentration factor (BCF) is <500 or the log K_{ow} <4 based on the GHS (UN, 2019). For those polymers that have no data on this endpoint, we assumed they would be not be bioaccumulative due to their large molecular size, which would prevent uptake in biological systems.

- **Persistence.** Based on the GHS (UN, 2019), ingredients are considered persistent if 0 to <20% of the ingredient degrades within 28 days, inherently biodegradable if 20 to <60% of the ingredient degrades within 28 days, and readily biodegradable if 60 to 100% of the ingredient degrades within 28 days. For those polymers that have no data on this endpoint, we assumed they would be persistent in water due to their polymeric nature. No biodegradation studies are available for MDI; thus, hydrolysis half-life was used to evaluate this endpoint, following California regulations (*i.e.*, 22 CCR § 69405.3; CalDTSC, 2012b).
- **Global Warming Potential (GWP).** We compared the functional ingredients to the greenhouse gases listed in Table 8.a.1 of the "Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC)" (IPCC, 2013). For functional ingredients that were described more generically (*i.e.*, by class of compound), we considered whether they are gases and whether they are chlorinated or fluorinated. Chemicals that are neither gases or chlorinated/fluorinated were considered to have negligible GWP.
- **Ozone-Depleting Potential (ODP).** US EPA's list of ozone-depleting substances (US EPA, 2018b) was used to evaluate this endpoint. For functional ingredients that were described more generically (*i.e.*, by class of compound), we considered whether they are gases and whether they are chlorinated or brominated (*i.e.*, based on the name provided). Chemicals that are neither gases or chlorinated/brominated were considered to have negligible ODP.
- **Clean Air Act VOC Contributing to Smog Formation.** We assessed whether each functional ingredient is a VOC; a chemical was considered to be a VOC if it had a vapor pressure equal to or greater than 0.1 mm mercury (Hg) based on criteria in CARB (2009).[18] Additionally, we noted whether the functional ingredient is listed as a substance exempted under 40 CFR § 51.100 (as per CARB, 2009). None of the identified VOCs are designated as exempted.

To meet the SCP regulations' requirement for an easily understood matrix of hazards, we adapted the color-coding system used by various hazard evaluation tools, such as the GreenScreen® hazard evaluation system (Clean Production Action, 2019). This employs a red/orange/yellow/green "heat map"-type color coding to allow the reader to easily compare the hazards of different chemicals at a high level. In addition, we added light grey shading to the endpoints for which no data were found (*i.e.*, data gaps). It should be noted that data gaps do not indicate a lack of toxicity; they merely indicate that no information was found.

Group B Endpoints

While ECHA REACH dossiers and Pharos (ECHA, 2020; Healthy Building Network, 2020) encompass most of the human health hazard endpoints required by the SCP regulations (*e.g.*, acute mammalian toxicity; CalDTSC, 2013), they do not address some of the target-organ-specific hazard traits, such as nephrotoxicity and cardiovascular toxicity. To a large extent, these types of specific toxicity are subsumed in the larger category of "systemic toxicity," which *is* addressed the in ECHA dossiers and Pharos(ECHA, 2020; Healthy Building Network, 2020). Nonetheless, to comply with the SCP regulations, we addressed these remaining health endpoints (*i.e.*, discussed herein after as "Group B" endpoints) by reviewing ECHA dossiers, supplemented by Australia Inventory Multi-tiered Assessment and Prioritisation (IMAP) assessments, for data on these particular health effects. We then qualitatively summarized the reported findings concerning these adverse effects or the lack of relevant adverse effects, as well as any data gaps (Table 5.3). Because sucrose (an ingredient in some Priority Products) does not have an ECHA dossier or IMAP assessment, we relied on a US FDA Generally Recognized as Safe (GRAS) status document (UL LLC, 2020) and a Cosmetic Ingredient Review article (Fiume *et al.*, 2019) for data on these endpoints. In conducting our

[18] The pMDI in the Priority Products has a vapor pressure well below 0.1 mm Hg, but as noted in Table 4.1, MDI is considered by CARB to be a low-vapor-pressure VOC with negligible potential to contribute to smog formation.

review, we focused primarily on repeated-dose studies, because these typically have the most detailed evaluation of potential health effects, whereas acute dosing studies often only examine a limited number of health effects using gross measures (*e.g.*, clinical signs, organ weight changes). This is a qualitative approach, but we believe that the alternative approach (creating an arbitrary and novel GHS-like scoring rubric for all of the additional SCP hazard endpoints that lack recognized classifications like the GHS) would be unreasonably burdensome and problematic, because, as noted above, many of these health effects are already addressed in the larger category of systemic toxicity. Lastly, the SCP regulations do not define each Group B endpoint. While some endpoints are straightforward, such as respiratory, cardiovascular, and digestive system toxicity, others are not. As a result, we took the following approaches for certain vague Group B endpoints:

- **Epigenetic Toxicity.** We noted from our review whether functional ingredients were or were not genotoxic. Genotoxicity generally implies changes in the DNA sequence, which is outside the scope of epigenetic toxicity, but genotoxicity also implies a potential for interaction with DNA, so it is evaluated given that more direct data on epigenetic effects are lacking. Lastly, we did not find other relevant information in our data sources regarding other types of DNA activity (*i.e.*, altered methylation).
- **Reactive in Biological Systems.** We were unable to make a determination about this relevant factor due to a lack of definition for this endpoint under the SCP regulations; thus, data gaps were assigned for all chemicals evaluated. All chemicals (*i.e.*, water, oxygen) are reactive in biological systems, so further clarification is needed.
- **Immunotoxicity.** We included respiratory and dermal sensitization as relevant under this endpoint, as these are immune system-mediated effects.

Again, it should be noted that the chemical-specific hazards presented in Tables 5.2-5.4 do not represent the potential hazards or risk of the associated final product, because the final SPF product is cured, unlike its individual chemical components.

5.1.1.1 Transformation Products

As required by the SCP regulations, we also identified the main transformation products of the functional ingredients and reviewed their potential toxicity (Table 5.5). We identified potential transformation pathways and products mainly *via* ECHA REACH dossiers (ECHA, 2020). We then reported the classified GHS hazards of the potential transformation products *via* the ECHA dossiers of the transformation products. Additionally, we noted if any transformation product is on the EU Persistent, Bioaccumulative, and Toxic (PBT) list, the California Toxic Air Contaminant (TAC) list, and/or the California Proposition 65 list, using Underwriters Laboratories Inc.'s (UL) List of Lists (LOLI) (UL LLC, 2020). As shown in Table 5.5, the main environmental transformation pathway for all functional ingredients is hydrolysis. The Priority Products, non-MDI-based alternative formulations, and lower-exposure approaches all have hazardous environmental transformation products (again, these are not transformation products of the cured foam but of the unreacted material). DuPont Patent No. WO 2013/101682 A1 has a transformation product that is present on the California TAC and California Proposition 65 lists (see Table 5.5). The Owens Corning example formulation has a transformation product that is present on the California TAC list (see Table 5.5). None of the products have transformation products that are on the EU PBT list.

5.1.2 Hazard Scoring Approach

Following CalDTSC's request in the Notice of Deficiency for an easy to understand comparative summary analysis in the form of a matrix that considers the percentage of each functional ingredient in each Priority Product and potential alternative, we quantitatively scored hazards of the functional ingredients using an adaptation of the Chemical Scoring Index (CSI). The CSI is a largely GHS-based tool for ranking the hazards of chemical ingredients in oil and gas products (Verslycke *et al*., 2014). The CSI considers not only the hazard but also the percentage of each chemical in the product formulation. These two pieces of information are combined using a scoring matrix to arrive at a total hazard score for the chemicals in the product. The original form of the CSI is heavily focused on acute toxicity hazards and did not have all the endpoints required under the SCP regulations (Verslycke *et al*., 2014), so some modifications to the CSI were required for this assessment. The modifications to the original CSI approach consisted of the following, and are also described in Tables 5.6-5.8:

- **Evaluating products in which there are no data for ingredients accounting for >30% of the product composition.** The original CSI approach did not evaluate products if "more than 30% of a product's composition is due to the contribution of components with 'No Data Available,'" with the idea that the product will be re-evaluated at a later time "when more information may be available" (Verslycke *et al*., 2014). We did not follow this approach, because the SCP regulations do not require additional testing, and the timeframe for compliance would not allow for this. Moreover, the non-MDI-based alternative formulations (where most of the data gaps lie) have not, for various reasons as described earlier, been commercialized, so new testing data for these are not expected. Thus, delaying the evaluation is not feasible and simply stating "cannot evaluate" also does not appear to meet CalDTSC's requirements. Several of the alternative products have no data for more than 30% of its composition (*i.e.*, DuPont Patent No. WO 2018/005142 A1, Dow Patent No. WO 2015/142564 A1, BASF Patent No. WO 2019/089237 A1; see Tables 5.2 and 5.4), and so were evaluated *via* an adapted approach, as described below.
- **Assigning a penalty for endpoint-specific data gaps.** The original CSI approach does not penalize data gaps on a *endpoint by endpoint* basis. It only penalized a product if <30% of its composition is accounted for by components with no data, with a maximum penalty score of 100 for the environmental categories, 100 for the human health categories, and 50 for the physical categories (if ≥30% of a product's composition is accounted for by components with no data, it would not be evaluated [see above]). Thus, the CSI lacks granularity in terms of how many or which health endpoints have missing data. For this Abridged AA, we added endpoint by endpoint penalty scores for data gaps, which is more conservative than the CSI's approach. These data gap scores were assigned based on hazard severity (*i.e.*, the maximum carcinogenicity and mutagenicity data gaps are scored 50 *versus* 10 for endocrine disruption). Also, in general, data gap penalty scores are lower than the Category 1 hazard scores for the same endpoint, and data gap penalty scores generally decrease with decreasing chemical concentrations, except for some categories of particular concern (*e.g.*, Category 1 carcinogens).
- **Chronic aquatic toxicity.** The CSI does not have scores for chronic aquatic toxicity; thus, the CSI's scoring system for acute aquatic toxicity was used.
- **Terrestrial toxicity and GWP.** The CSI does not have scores for terrestrial toxicity or GWP; thus, scores for these metrics were created.
- **Mutagenicity, reproductive/developmental toxicity, and systemic toxicity single- and repeated-dose toxicity.** Under the original CSI approach, scores did not differ between the GHS subcategories for mutagenicity, reproductive/developmental toxicity, and systemic toxicity single- and repeated-dose toxicity. To provide more granularity in the scoring, for this Abridged AA, we

adopted the maximum CSI score for Category 1 for all of the abovementioned hazard endpoints, but scaled down to a lower score for subsequent subcategories (approximately 50% of the Category 1 score for Category 2, and so on). This approach is in line with the spirit of the GHS and CSI. Note that the CSI implemented lower scores for Categories 2 and below for carcinogenicity, corrosivity, and acute mammalian and aquatic toxicity, but not for the four abovementioned endpoints.

- **Endocrine.** We moved the endocrine hazard endpoint from ecological toxicity to human health toxicity. Additionally, we used a score of 25, instead of the original 50 in the CSI, for endocrine disruptors, because the EU's Endocrine Disruptor Priority List, which we used for this assessment, is a listing of chemicals with endocrine *concern* that should be explored *via* testing, rather than a list based on studies showing actual effects. In contrast, the maximum score for mutagenicity is 50 and is based on positive findings of a mutagenic effect.
- **Skin and respiratory sensitization.** We created separate skin and respiratory sensitization categories from the original CSI's "sensitizer" category, to be consistent with the SCP regulations' toxicity categories. Additionally, we used a maximum score of 50, instead of the original 25 in the CSI, for skin and respiratory sensitization. This is because the original CSI approach was developed for oil and gas applications, in which sensitization was less of an issue. Because sensitization is an important hazard for spray foam insulation and consumer products in general, we increased the maximum score for these endpoints.
- **VOCs contributing to tropospheric ozone formation.** We used a maximum score of 75, instead of the original 50 in the CSI, for this endpoint. Because this is an important hazard for products such as spray foam insulation that are used in urban areas, and because smog formation is a particular concern for California cities, we increased the maximum score for this endpoint.
- **Eye and skin irritation.** We created separate categories for eye and skin irritation from the "irritant" category in the original CSI to be more consistent with the required SCP regulations' toxicity categories. We assigned a maximum data gap penalty score of 25 for products in which components with no data account for more than 30% of the composition, matching the score of 25 for Category 1 skin or eye irritants, because these are common hazards.

When the original CSI approach provided numerical scoring values for an endpoint, we used those scores, other than the abovementioned deviations for endocrine disruption, skin and respiratory sensitization, and VOCs contribution to tropospheric ozone formation. When scores for endpoints were created, we employed scores that were consistent with similar endpoints (*e.g.*, we used the same scoring used for "irritation" in the original CSI approach for the new eye and skin irritation scores). In our scoring approach, we did not score Group B endpoints (Table 5.3), because any adverse effects that rise to the level of GHS classification would already be captured under the single target organ toxicity – repeated exposure endpoint, and we wanted to avoid "double counting."

5.1.3 Hazard Scoring Results

As shown in Table 5.2, the lower-exposure approaches have hazards that are essentially identical to the Priority Products, which is to be expected, as they are also MDI-based products (and thus are Priority Products themselves). Two of the six non-MDI-based alternative formulations we assessed (*i.e.*, the Owens Corning formulation and DuPont Patent No. WO 2013/101682 A1; see Table 5.2) contain ingredients that share the same respiratory sensitization concern as the MDI in the Priority Products. Considering the fact that respiratory sensitization and workplace asthma are the primary reasons why pressurized, two-component SPF products were selected as Priority Products by CalDTSC (2014), the Owens Corning formulation and DuPont Patent No. WO 2013/101682 A1 may not be suitable replacements for the Priority

Products under the SCP regulations. Because we have no composition information for NanoSonic HybridSil, it is unclear if this potential alternative would also contain respiratory-sensitizing chemicals. Additionally, it is unclear if there are additional respiratory sensitizers present in the remaining products, because many of the functional ingredients have data gaps for this endpoint. As mentioned above, a lack of data does not indicate a lack of toxicity; it merely indicates that no information was located, perhaps due to lack of testing.

In addition, some of the non-MDI-based alternative formulations contain functional ingredients that have hazards that are not present in the Priority Products' functional ingredients (*i.e.*, reproductive/developmental toxicity and endocrine disruption). For example, the functional ingredients in Hybrid Coatings Technologies/Nanotech Industries Green Polyurethane and the Owens Corning formulation contain a BPA epoxy resin that is on the EU's Endocrine Disruptor Priority List (UL LLC, 2020). The Owens Corning formulation also contains BPA, which is listed on the EU's Endocrine Disruptor Priority List and California's Proposition 65 list for reproductive toxicity (UL LLC, 2020). In addition, another functional ingredient in the Owens Corning formulation (cycloate A) is listed under California Proposition 65 for developmental toxicity (UL LLC, 2020).

As shown in Tables 5.2 and 5.4, and summarized in Table 5.5,[19] the difference in physical hazard scores between the Priority Products and the potential alternatives is minimal. There is a wider range for the environmental scores, from 0 (generic Group 2 Priority Products and Firestone/Gaco Profill System) to 470 (Owens Corning formulation). The largest hazard contributor is human health, with scores ranging from 255 (generic Group 2 Priority Products and Firestone/Gaco Profill System) to 755 (Owens Corning formulation). For some alternatives, there is a possible trade-off between human health and environmental scores; for example, Firestone/Gaco Canary has a slightly lower human health score *versus* the relevant Priority Product group (445 *vs*. 555 for Group 3 Priority Products) but a higher environmental score (220 *vs*. 150 for Group 3 Priority Products), although the latter difference is largely due to data gaps.

- As summarized in Table 5.5, the hazard scores for the non-MDI-based alternative formulations were similar to, and sometimes higher (*i.e.*, more hazardous) than, those of the comparable generic Group 2 and 3 Priority Products. While these alternatives do not contain MDI, they still employ reactive chemistry, often with hazardous amines as the functional ingredients, resulting in trading one hazardous ingredient for another (which could potentially be a regrettable substitution). Additionally, there are many data gaps for the non-MDI-based alternative formulations (as well as for the polyols in the Priority Products). It is unclear how the non-MDI-based alternative formulations would compare to the Priority Products if more data were available.
- The hazard scores for Firestone/Gaco Profill System and Nitrosys/ICP HandiFoam HVLP MD 2.0 are comparable to the equivalent generic Priority Products (Groups 2 and 3, respectively), which is unsurprising, considering the fact that they also use MDI as a functional ingredient and generally have the same or similar functional ingredients.
- The hazard score for the lower-exposure approach BASF Patent No. 9592516 B2 is within the range of the scores for the comparable generic Priority Products (Group 2 or 3).
- The hazard score for the lower-exposure approach BASF Patent No. WO 2019/089237 A1 is substantially higher than any of the generic Priority Products, due to its many data gaps. Note that there's no enough information in the BASF patent to assign product grouping.

[19] A hazard score is not available for Group 4 Priority Products (high pressure, closed cell, 3 lbs/ft^3), because no generic formulation exists for this group.

It is important to stress that although the hazard scores are quantitative in nature, these scores should not be used as strict demarcations due to the underlying uncertainties (see Section 8 for more information). They should be thought of as approximations. Overall, the available data suggest that there is no non-MDI-based alternative formulation that is clearly preferable to the Priority Products in terms of ingredient hazards. Certain data gaps (*e.g.*, for Firestone/Gaco Canary, Hybrid Coatings Technologies/Nanotech Industries Green Polyurethane, Dow Patent No. WO 2015/142564 A1, DuPont Patent No. WO 2018/005142 A1, and BASF Patent No. WO 2019/089237 A1) would need to be filled in order to reach more definitive conclusions.

5.2 Performance

A complete set of necessary performance information was lacking for each non-MDI-based alternative formulation (and some had no such information available). Performance information was also lacking for many of the lower-exposure approaches (which are also Priority Products).

In response to a suggestion from CalDTSC, the REs attempted to predict mixture-level physicochemical properties as a proxy for potential product performance using the Organisation for Economic Co-operation and Development (OECD) Quantitative Structure-Activity Relationship (QSAR) Toolbox (OECD, 2020). However, the REs were unable to predict mixture-level physicochemical properties for any of the non-MDI-based alternative formulations, due the lack of CAS Nos. for one or more ingredient(s) in every formulation. In some circumstances, the ingredients were synthesized in a laboratory and have not been registered with CAS. The REs were also unable to identify simplified molecular-input line-entry system (SMILES) notations for some ingredients with identified CAS Nos. due to their chemical nature (*i.e.*, oligomer or polymer), thus limiting the usability of the OECD QSAR Toolbox. Additionally, no QSAR models exist for chemical reactivity, density, flammability, flash point, oxidation-reduction potential, and oxidizing properties in OECD QSAR Toolbox (OECD, 2020).

Lastly, we found that it was not possible to predict product physical-chemical properties from the individual ingredients, because the chemical reaction to produce polyurethane foam has too many variables. The ingredients and the percentages in the non-MDI-based alternative formulations are not set and will likely change if the products are brought to market. For example, based on the REs' professional opinions, the technologies described in the Owens Corning formulation and Hybrid Coatings Technologies/Nanotech Industries Green Polyurethane patents (discussed in Section 4.3.1) are likely slow-reacting and more suited for coatings rather than spray foam. QSAR predictions also do not take into consideration that the product itself would be a solid reacted foam, while the ingredients are liquid. For example, vapor pressures are available for most ingredients, but the solid reacted foam would have a negligible vapor pressure due to its physical state. Additionally, variables such as application method (*i.e.*, spraying *versus* pouring), application pressure, temperature, catalyst levels, and reactivity will all influence the final product's exposure potential and/or performance. Ultimately, there are too many unknown variables to make assumptions on potential exposure and/or performance without commercially available versions of the chemistries available to evaluate product emissions and performance per standardized tests, such as those included in AC 377 (ICC-ES, 2018). While we were unable to use OECD QSAR Toolbox to predict product-level performance, we have included the available performance data in Table 5.10.

As outlined in Section 3.6, AC 377 (ICC-ES, 2018) outlines the mandatory physical properties and standard test methods required for all SPF products, including any alternatives. These properties include thermal resistance (ASTM C177, C518, or C1363), core density (ASTM D1622), tensile strength (ASTM D1623), dimensional stability (ASTM D2126), compressive strength (ASTM D1621), adhesion (ASTM D1623), and/or surface burning characteristics (ASTM E84 or UL 723), depending on the SPF application.

- Performance data based on the generic Priority Product are not available. As such, a singular product (and its performance data) was selected to represent each group. As all products in a given group must meet the same minimum performance criteria, this was considered a reasonable solution to the problem of tabulating performance data for over 170 Priority Products, which would have been difficult for readers to navigate. Specific information on the performance of each Priority Product can be found in the Product or Technical Data Sheets (PDSs or TDSs) for the products, which are typically available on the manufacturers' websites. The example products were selected to ensure a wide representation of companies. Representative products were selected from each selected RE because the products have publicly available TDSs and third-party certifications. As shown in Table 5.10, all of the representative Priority Products meet their respective group's AC 377 performance criteria. Additionally, the representative products are certified by various third parties to meet the building codes outlined in the IBC, IRC, and IECC.

- As shown in Table 5.10, some lower-exposure approaches (*i.e.*, Firestone/Gaco Profill System and HVLP system products such as Nitrosys/ICP HandiFoam HVLP MD 2.0), also meet the minimum performance requirements for SPF products as dictated by AC 377, which is expected because they are also commercially available Priority Products. They also meet various additional building codes, such as the IBC, IRC, and IECC.

- Almost no performance information is available for the two BASF patents for lower-exposure approaches (No. 9592516 B2 and 2019/089237 A1; Wishneski *et al*., 2017, 2019). According to a conversation with BASF, the technologies described in these two patents were unable to meet one or more required performance parameters, but further research and development work on them is ongoing. No further information is available on the approaches described in these patents. Note that BASF is submitting CBI to CalDTSC, but it is unclear what that submission will include.

- Performance data were largely unavailable for the non-MDI-based alternative formulations (and some had no such information available).

  - The patent for Firestone/Gaco Canary proposes many core densities, ranging from 0.1 (open cell) to 30 lbs/ft^3 (closed cell) (Trumbo, *et al*., 2016). According to communications with Firestone/Gaco, Canary did not achieve the desired R-value and K-factor per ASTM C518 and had shortcomings in passing some code requirements, such as the ASTM E84 burn performance criteria. Firestone/Gaco indicated that no performance information is available for Canary for the rest of the AC 377 parameters (*i.e*., tensile strength, dimensional stability, and compressive strength).

  - While the patent for the Owens Corning formulation (Olang, 2012) reported limited information on an R-value range for the formulation ("maybe… about 3 to 7 [ft^2·°F·h/BTU] per inch"), it was not supported by validated test data (Olang, 2012, p. 12). The patent did not have information on the rest of the AC 377 criteria.

  - The patent for Hybrid Coatings Technologies/Nanotech Industries Green Polyurethane (Figovsky *et al*., 2015) reported core density, R values, compressive strength, and "validated fire resistance," but the R-values fell below the minimum for the required core density for this type of product (3 to 4.7 *versus* a minimum of 5.8, according to Appendix JA4 of the California Energy Commission Building Energy Efficiency Standards [California Energy Commission, 2018b]). The patent also did not report the test methods used or other criteria, such as tensile strength, dimensional stability, and actual flame-spread or smoke-development indices.

  - According to communications with DuPont, Patent No. WO 2013/101682 A1 (Jin *et al*., 2013) did not have a working catalyst capable of meeting the performance requirements needed for the product. The technology was able to yield a foam that had dimensional stability, but the exact dimensional stability value was not reported. The patent also reported compressive strengths that met the criteria for Group 3, but not Group 4, Priority Products. Additionally, the reported surface burning characteristics met the AC 377 criteria. While reaction time and shelf life are not performance criteria defined in AC 377, significant deficiencies, including long cure times and poor shelf life (<2 months), made Patent No. WO 2013/101682 A1 non-viable as a commercial product. Due to these performance issues, DuPont decided to cease further research and development on this technology.

- Similarly, according to communications with DuPont, Patent No. WO 2018/005142 A1 (Thomas *et al*., 2018) did not meet the dimensional stability requirements as defined by AC 377. It was not hydrolytically stable (degrades in the presence of heat and moisture), which, given the typical ambient moisture seen in the buildings in which the product is intended to be used, makes it non-viable. The formulation was so unstable that DuPont was not able to run typical physical property tests nor to spray the foam; thus, all the work on the formulation was done as "cup" chemistry on the bench. Due to these performance issues, a decision was taken to cease further research and development on this technology.
- Very little performance information was available in Dow Patent No. WO 2015/142564 A1 (Foley *et al*., 2015), but the patent did provide a compressive strength value that does not meet AC 377 criteria (4.06 pounds per square inch [psi] *versus* the AC 377-specified minimum of 15 psi) and an example core density. The patent did not have information on the rest of the AC 377 criteria. No additional information was available from Dow, which is not one of the REs working on this Abridged AA.

In addition to those requirements outlined in AC 377, all SPFs, including any non-MDI-based alternative formulations, must conform to local VOC emission limits in California and all additional requirements laid out in building standards, as noted in Section 3.6 (none of which are addressed in the alternative formulations' patents). Lastly, in addition to performance, many of the patents are based on the use of blowing agents (HFC-245fa, HFC-134a, and HFC-365mfc) that were banned in California in 2020 for high-pressure SPF products and alternatives, and will be banned in 2021 for low-pressure SPF products and alternatives (CARB, 2018a). The use of new lower-GWP blowing agents would likely require adjusting other ingredients in the product formulations, which could impact some of the performance results.

5.3 Exposure

5.3.1 Product-level Emission Data

Regarding the functional ingredients of the lower-exposure approaches and Priority Products (*i.e.*, MDI and polyols), limited product-level emission data are available for MDI, while no such information is available for the polyols. Thus, we relied on MDI emission data to compare the product-level emissions of the generic Priority Products and lower-exposure approaches (Table 5.11).

As shown in Table 5.11, product-level MDI emission data are available for the generic Priority Products[20] and all four lower-exposure approaches, including the two BASF patents. However, the sampling protocols used to determine these emissions varied substantially among these products and patents (*i.e.*, ventilation and time point), thus, direct comparisons of the emission data across studies would be inappropriate.

[20] Product-level emission data are not available for Group 4 Priority Products (high pressure, closed cell, 3 lbs/ft^3), because no generic formulation exists for this group.

The available emission test data consist of the following:

- Wood (2017) reported MDI emissions for the generic Priority Products *with* active ventilation of 10.4, 233, and 598 air changes per hour (ACH) *during and after* SPF application. Active ventilation is the industry workplace standard for SPF application, although Wood (2017) noted that ACH of 233 and 598, while achievable in the laboratory setting, are not realistic or likely feasible on a construction site. Based on the technical infeasibility of achieving 233 and 598 ACH on a work jobsite, Table 5.11 only summarizes the MDI emission data from 10.4 ACH in this study for comparison purposes. Lastly, in addition to emissions for 4,4-MDI (CAS No. 101-68-8), Wood (2017) also reported emissions for 2,4-methylene diphenyl diisocyanate (2,4-MDI; CAS No. 5873-54-1) and pMDI (CAS No. 9016-87-9). Because emissions for 2.4-MDI are considerably lower than those for 4,4-MDI, and because the other product emission studies in this section mostly reported 4,4-MDI emission data, we only summarized the reported 4.4-MDI emission data from Wood (2017) in Table 5.11. We also did not include pMDI emission data in Table 5.11, because pMDI is not measured in the other emission studies. In addition, regulatory values for MDI, such as the ACGIH TWA TLV (ACGIH, 2019), are for 4,4-MDI (CAS No. 101-68-8).
- ICP Building Solutions Group (c. 2020) reported MDI emissions for Nitrosys/ICP HandiFoam HVLP MD 2.0 *with* active ventilation of 20 ACH at 1 hour after application. Again, active ventilation is the industry workplace standard for SPF application.
- Conversely, Nelson (2015) and Wishneski *et al*. (2017) reported MDI emissions for Profill System and BASF Patent No. 9592516 B2, respectively, *without* ventilation and *during* SPF application.
- Wishneski *et al*. (2019) reported MDI emissions for BASF Patent No. WO 2019/089237 A1 *with* active ventilation (10 and 20 ACH) and *during* SPF application.

Within each study, certain conclusions can be made, but only limited comparisons across studies can be made due to the different study protocols used. MDI emissions were not detected at 30 minutes and 1 hour after application for the generic Priority Products (Groups 1, 2, and 3) (Wood, 2017). They were also not detected 1 hour after application for Nitrosys/ICP HandiFoam HVLP MD 2.0 (Group 1) (ICP Building Solutions Group, c. 2020). No emission data are available at 30 minutes after SPF application for HandiFoam HVLP MD 2.0.

Wood (2017) reported that MDI was detected *during* application and *with* 10.4 ACH at the location of the applicator for generic high-pressure, medium-density (average of 0.0268 ppm); high-pressure, low-density (average of 0.0153 ppm); and low-pressure (average of 0.0016 ppm) Priority Products. Unfortunately, no MDI emission data are available *during* SPF application for Nitrosys/ICP HandiFoam HVLP MD 2.0.

Unfortunately, no comparable MDI emission data exist for Firestone/Gaco Profill System *with* ventilation. The only Profill System emission data are available for application *without* ventilation (*i.e.*, closed windows and no fans, an atypical situation) and during SPF application. In a single study with no ventilation, which is not recommended for the application of traditional SPF or Profill System, potential worker exposure to MDI was lower with Firestone/Gaco ProFilm (0.0076 ppm) and ProWeb products (0.0010 ppm) compared to standard low-density, high-pressure SPF (0.3 ppm) (Tables 4.1 and 5.11; Nelson, 2015). No emission data were reported for the GacoProCap System. Note that the ACGIH TLV for MDI averaged over an 8-hour period is 0.005 ppm or 5 ppb (ACGIH, 2019), so MDI emission concentrations for ProFilm, but not ProWeb, still exceeded the TLV. Regardless of the MDI emission data, according to Firestone/Gaco, use of any of the Profill Systems still requires full PPE, particularly in case of mishap. Again, no information was available in the Profill System study regarding potential MDI exposure levels after SPF application (Nelson, 2015).

Similarly, there are no comparable emission data for BASF Patent No. 9592516 B2 *after* SPF application. Comparative emission data are available for the time *during* SPF application for this lower-exposure approach (Wishneski *et al*., 2017), as measured in a laboratory setting. The patent indicates that exposure to MDI was lower with the BASF spray nozzle (0.0233 ppm 2.5 ft from the cardboard surface and 0.0033 ppm 10 ft from the cardboard surface) compared to a "generic application system" (0.059 ppm 2.5 ft from the cardboard surface and 0.007 ppm 10 ft from the cardboard surface) (Wishneski *et al*., 2017). Note that the ACGIH TLV for MDI averaged over an 8-hour period is 0.005 ppm or 5 ppb (ACGIH, 2019), so MDI concentrations at 2.5 ft still exceeded the TWA TLV and wearing PPE would be required. Additionally, the patent for this lower-exposure approach did not report whether the study employed ventilation, which is the industry workplace standard. The test was performed against cardboard surfaces in a laboratory rather than against construction materials in an actual construction site. Lastly, the patent describes the technology to "minimize a need to use respirators and protective equipment," but makes no claim as to whether PPE are needed or not (Wishneski *et al*., 2017).

Lastly, BASF Patent No. WO 2019/089237 A1 (Wishneski *et al*., 2019) reported average MDI emissions of 0.012 ppm at the applicator's location *with* active ventilation of 10 ACH and *during* SPF application. Comparisons can be made with the MDI emissions reported in Wood (2017) for the generic Priority Products, which were also measured at the applicator's location *with* active ventilation of 10.4 ACH and *during* SPF application. MDI emission from the approach described in BASF Patent No. WO 2019/089237 A1 was approximately half that from generic high-pressure, medium-density SPF; nearly the same as that from generic high-pressure, low-density SPF; and several times higher than that from generic low-pressure SPF (Wood, 2017). Unfortunately, not enough information is available in BASF Patent No. WO 2019/089237 A1 to assign the correct comparable product grouping, so a direct comparison between the lower-exposure described in this patent and the most equivalent Priority Product group cannot be made. Lastly, no statement regarding PPE was found in the patent.

In summary, while product-level MDI emission data are available for the generic Priority Products and the lower-exposure approaches, it is inappropriate to make direct comparisons between all the data due to the substantially different sampling protocols used to collect them. However, certain comparisons can be made within studies and between studies that used similar protocols. There is no difference in post-application MDI emission between the generic Priority Products (Groups 1, 2, and 3) and Nitrosys/ICP HandiFoam HVLP MD 2.0 (Group 1). Exposure to MDI during application was lower with Firestone/Gaco ProFilm and ProWeb products compared to that with standard low-density, high-pressure SPF, but these data were collected in a singular study that was done without ventilation (Nelson, 2015). Exposure to MDI during application of BASF Patent No. 9592516 B2 (Wishneski *et al*., 2017) was lower compared to exposure to MDI while using a "generic application system," but ventilation was not mentioned in the patent's description of this study, and the study was conducted in a laboratory rather than an actual field setting. MDI emission measured with active ventilation and during application of BASF Patent No. WO 2019/089237 A1 (Wishneski *et al*., 2019) were approximately half that of generic high-pressure, medium-density SPF; nearly the same as that of generic high-pressure, low-density SPF; and 7.5 times higher than that of generic low-pressure SPF (Wood, 2017). However, not enough information is available on BASF Patent No. WO 2019/089237 A1 to assign the correct comparable product grouping, so a direct comparison between the lower-exposure described in this patent and the most equivalent Priority Product group cannot be made. Ultimately, all of the lower-exposure approaches are still Priority Products and require applicators to wear appropriate PPE.

5.3.2 Ingredient-level Physicochemical Data

There are no product-level emission data for the non-MDI-based alternative formulations. As a result, we gathered ingredient-specific physicochemical data for all the functional ingredients of these alternative formulations (Table 5.12), as suggested in CalDTSC's "Alternatives Analysis Guide" (CalDTSC, 2017a). We also gathered ingredient-specific physicochemical data for all the functional ingredients in the lower-exposure MDI-based approaches, for the sake of completeness.

It is important to stress that while ingredient-specific physicochemical data are presented in Table 5.12, ingredient-specific data may not reflect the product-level exposure potential of the actual final product when fully cured and installed. For example, the water solubility value (10,000 mg/L) of the Firestone/Gaco Canary ingredient MXDA (CAS No. 1477-55-0) suggests that the substance is soluble in water, but the final product is a solid foam and would have negligible solubility in water.

For Table 5.12, we consulted experimental, modelled, and estimated data from a variety of sources, including study reports, mainly from ECHA REACH dossiers (ECHA, 2020) and US EPA's EPI Suite software (US EPA, 2019a). In Table 5.12, all experimental values are bolded to differentiate between experimental and modeled or estimated data. Similar to the hazard information, there are many data gaps regarding information on the physicochemical properties of the possible alternatives' ingredients, particularly those that do not have ECHA REACH dossiers or are polymers, mixtures, or unknown or variable compositions, complex reaction products, and biological materials (UVCBs). Polymers, mixtures and UVCBs cannot be modeled in programs such as EPI Suite, due to a lack of a SMILES and a reliable underlying dataset. In addition, Gradient did not color-code this table, because no color-coding was provided by the various data sources and because it would be difficult to assign relative preferences for many of the relevant factors.

Many of the physicochemical parameters are not materially relevant given how SPF products are used (*e.g.*, melting point is not relevant because the SPF products are already liquids at feasible use conditions, boiling point is not relevant because SPF products are not heated to boiling, and volatility is addressed *via* the vapor pressure parameter). For those endpoints that would be materially relevant for SPF products (*e.g.*, log octanol-water partition coefficient [K_{ow}], log organic carbon partition coefficient [K_{oc}], vapor pressure, and water solubility), we used the following criteria from US EPA's "Interpretive Assistance Document for Assessment of Discrete Organic Chemicals" (US EPA, 2013) for the evaluation of ingredients' exposure potential in air, water, soil, sediment, and groundwater *via* soil and sediment:

- **Vapor Pressure – Estimated by MPBPWIN:**
  - $\geq 10^{-4}$ = Chemical mostly in the vapor (gas) phase.
  - 10^{-5} to 10^{-7} = Chemical in the vapor and particulate phase.
  - $\leq 10^{-8}$ = Chemical mostly in the solid phase.
  - For chemicals with a vapor pressure < 10^{-6}, there is low concern for inhalation exposure.[21]

[21] There would be increased inhalation potential when ingredients are heated or sprayed, as is done with all the Priority Products and potential alternatives but vapor pressure data are typically available only at standard temperature, not the elevated temperatures used in foam application.

- **Water Solubility (mg/L) – Estimated by WSKOWWIN:**
  - >10,000 = Very soluble.
  - >1,000-10,000 = Soluble.
  - >100-1,000 = Moderate solubility.
  - >0.1-100 = Slightly soluble.
  - <0.1 = Negligible solubility.
- **Log K_{ow} – Estimated by KOWWIN:**
  - <1 = Highly soluble in water (hydrophilic).
  - >4 = Not very soluble in water (hydrophobic).
  - >8 = Not readily bioavailable.
  - >10 = Not bioavailable – difficult to measure experimentally.
- **Log K_{oc} – Estimated by PCKOCWIN:**
  - >4.5 = Very strong sorption to soil and sediment; negligible migration potential to groundwater.
  - 3.5-4.4 = Strong sorption to soil and sediment; negligible to slow migration potential to groundwater.
  - 2.5-3.4 = Moderate sorption to soil and sediment; slow migration potential to groundwater.
  - 1.5-2.4 = Low sorption to soil and sediment; moderate migration potential to groundwater.
  - <1.5 = Negligible sorption to soil and sediment; rapid migration potential to groundwater.

The physical-chemical data in Table 5.12 were examined in the context of the abovementioned US EPA criteria to look for differences among the different functional ingredients. The results of the comparison are included in Table 5.13. As summarized in Table 5.13, the functional ingredients in the Hybrid Coatings Technologies/Nanotech Industries Green Polyurethane patent have lower exposure potential *via* air compared to the functional ingredients in the generic Priority Products. Conversely, the functional ingredients in Firestone/Gaco Canary and Profill System, Dow Patent No. WO 2015/142564 A1, and DuPont Patent WO 2018/005142 A1 have somewhat comparable or higher exposure potential compared to the functional ingredients in the generic Priority Products. The exposure potentials of the functional ingredients in HVLP systems (*e.g.*, Nitrosys/ICP HandiFoam HVLP MD 2.0) and BASF Patent No. 9592516 B2 are similar to those of the functional ingredients in the generic Priority Products. The exposure potentials of some functional ingredients in the Owens Corning formulation and DuPont Patent No. WO 2013/101682 A1 were higher than those of the functional ingredients in the generic Priority Products, while the exposure potentials of other functional ingredients in these alternative formulations were lower. Lastly, no conclusions regarding exposure potential could be drawn for the functional ingredients in BASF Patent No. WO 2019/089237 A1 due to lack of CAS Nos. and the inability to perform modeling for polymer ingredients.

While this qualitative exercise provided some insight into the ingredient-level exposure potential of the possible alternatives, ideally, we would compare the product-level exposure data, because the ingredients are meant to react and create a foam structure that is distinctly different from the individual ingredients. Unfortunately, no product-level exposure information is available at this time for the non-MDI-based alternative formulations.

5.4 Cost

5.4.1 Relative and Approximate Product Costs

We could not evaluate product costs between the Priority Products and most of the potential alternatives, because most of the potential alternatives are not commercially available. If commercialized, there may be cost differences between the Priority Products and the potential alternatives, as well as potential economic impacts on consumers and industry.

As requested by CalDTSC, recent approximate costs for the Priority Products are as follows.

- **Low Pressure (Home Depot, 2020; Lowe's, 2020):**
  - Cost estimated for 1 inch of insulation.
  - Cost per square board foot: $1.20-3.20.
  - Cost per square board foot per R-value: $0.21-0.58, assuming R values of 5.5-6.2.
- **High Pressure, Open Cell (US DOE, 2010):**
  - Cost estimated for 3.5 inches of insulation.
  - Cost per square board foot:[22] $1.70-2.50.
  - Cost per square board foot per R-value:[22] $0.13-0.20, assuming an R-value of 12.6.
- **High Pressure, Closed Cell (US DOE, 2010):**
  - Cost estimated for 1 inch of insulation.
  - Cost per square board foot:[22] $1.30-2.00.
  - Cost per square board foot per R-value:[22] $0.20-0.31, assuming an R-value of 6.5.

Two of the lower-exposure approaches (*i.e.*, Firestone/Gaco Profill System and Nitrosys /ICP HandiFoam HVLP MD 2.0) are commercially available as insulation for commercial and residential walls, basements, and roofs. However, as discussed in Sections 4.2 and 6.1, it is the REs' position that a Priority Product cannot be considered a safer alternative to another Priority Product without a clear AAT. The Firestone/Gaco Profill System SPF component is not expected to cost more than other high-pressure SPF. However, applicators must purchase plastic membranes or aluminum guides to use the product. There will be some additional labor cost associated with preparing the worksite (*i.e.*, applying the membrane). However, it seems reasonable to expect that some of the additional upfront labor would be offset by decreased post-application work (*i.e.*, trimming and cleanup). HVLP SPF systems are expected to cost more than traditional low-pressure kits but less than high-pressure SPF systems.

5.4.2 External Costs

According to the SCP regulations, REs submitting an Abridged AA must evaluate both internal and external costs of the priority product and any alternatives. Internal costs are those borne by the REs for developing, producing, marketing, and managing a Priority Product or any alternatives. External costs are those borne

[22] Costs include materials and estimated labor.

by third parties. The SCP regulations discuss three broad categories of external costs: what may be termed public health costs, environmental costs, and waste management and restoration costs:

> The responsible entity shall evaluate, monetize, and compare for the relevant exposure pathways and life cycle segments the following impacts of the Priority Product and the alternatives:
>
> 1. Public health and environmental costs; and
> 2. Costs to governmental agencies and non-profit organizations that manage waste and oversee environmental cleanup and restoration efforts, and/or are charged with protecting natural resources, water quality and wildlife. (22 CCR § 69505.6[a][3]; CalDTSC, 2013)

5.4.2.1 Public Health Costs

Public health costs are the costs for providing health care to individuals as a result of exposure to a Priority Product and any alternatives that are borne by the individuals themselves, government agencies, insurance companies, hospital systems (in the case of people without insurance), or employers (in the case of workers' compensation). In order to develop an estimate of such costs, one first needs to identify the health effect(s) of concern. Evaluating generic symptoms (*e.g.*, nasal congestion, itchy skin, altered breathing) is problematic because these are not studied in a consistent manner and cannot be attributed to particular exposures. In order to evaluate costs, it is necessary to have a clear diagnostic criterion that allows for comparison across studies and that is tracked by medical systems as to cost.

For isocyanate exposure that occurs primarily *via* the respiratory route, the most reported and best studied adverse health effect is occupational asthma (CalDTSC, 2017b). Asthma has clear diagnostic criteria (*e.g.*, *via* pulmonary function testing) and its incidence and the costs associated with it have been studied. Although other health effects can occur from exposure to isocyanates (skin sensitization, respiratory irritation, pneumonitis, more generalized breathing problems), asthma is better described in the literature and can be more specifically associated with inhalation exposure to isocyanates among SPF workers.

In order to monetize the cost associated with occupational asthma from exposure to the Priority Products and any alternatives, the following equation can be used:

$$\text{Public Health Cost} = \text{Number of Occupational Asthma Cases in SPF Workers} \times \text{Cost to Treat Each Case}$$

Thus, in order to carry out the analysis for the Priority Products, two types of information are required: the number of cases of occupational asthma in California due to exposure to the Priority Products (either as the raw number of cases or as a prevalence value that can be multiplied by the number of SPF workers in the industry), and the cost of treating a single case of occupational asthma in California (ideally specific to isocyanate-related asthma, if the cost differs from other types of asthma cases).

The same information would be required for the potential alternatives. Because an evaluation of the public health costs of the alternatives would be meaningless unless it can be compared to the public health costs of the Priority Products, we first focused on examining whether sufficient data to characterize the public health costs of the Priority Products could be located.[23] The following section describes a literature review we carried out in an attempt to obtain these data.

---

[23] Clearly, for the patent alternatives, which are not being used in the marketplace, data on occupational asthma associated with their use will not be available. For the lower-exposure approaches (which contain MDI/pMDI), we would not expect data to be available if it is not available for the standard Priority Products. No specific studies of asthma among SPF workers using only

Data on the Number of Occupational Asthma Cases Attributable to SPF

We carried out two types of searches in order to attempt to obtain this information:

- Searches *via* the National Library of Medicine database using the following search terms: "spray foam," "disease," and "polyurethane"; "spray foam," "asthma," and "polyurethane"; "SPF," "disease," and "polyurethane"; and "SPF," "asthma," and "polyurethane." All search results were examined to determine if they were useful.
- Searches *via* Google using the following search terms: "spray foam," "asthma," and "incidence"; "spray foam," "asthma," and "prevalence"; and "spray foam," "asthma," and "cases." The first 120 results of each search were examined to determine if they were useful.

Generally, data are available on the rates of occupational asthma in general, although these are often described as uncertain. Among occupational asthma cases, isocyanate allergy is frequently described as a leading cause or a significant cause, but without quantitation. For example, Verschoor and Verschoor (2014) give 5-15% as the prevalence rate for "health complaints" among all isocyanate workers (not just those exposed to pMDI or just those working with SPF). As noted in CalDTSC's technical support document for the Priority Product listing, there are a number of case reports of individuals who have had allergic reactions to SPF (CalDTSC, 2017b), but these are not useful for establishing the total number of occupational asthma cases or the prevalence of occupational asthma in the SPF industry.

In 2013, CDPH published a report titled "Asthma in California: A Surveillance Report" that summarized asthma statistics for the entire state, including among workers (CalDPH, 2013). The report noted that "almost 3 million" California residents currently had asthma (CalDPH, 2013). The report noted that in 2010, there were approximately 35,000 hospitalizations and 180,000 emergency department visits associated with asthma (all types, not only occupational asthma). The authors also estimated that "over 974,000 adults in California have asthma that has been caused or aggravated by their work, but work-related asthma (WRA) is often not recognized or diagnosed" (CalDPH, 2013). The report states:

> Some industries with the highest rates of WRA include local transit, hospitals, zoos and parks, utilities, social services, manufacturing of lumber and wood products, heavy construction, and electrical equipment manufacturing. Some specific occupations with the highest rates of WRA include firefighters, science technicians, medical assistants, telephone operators, chemical technicians, respiratory therapists, correctional officers, and chemical machine operators. The most common substances that people with WRA report they are exposed to at work are dust, chemicals, smoke, mold, indoor air pollutants, paint, and cleaning materials. The most common asthmagens that people with WRA are exposed to are latex, formaldehyde, glutaraldehyde, diisocyanates, sulfuric acid, rat antigens, epoxies, and California Redwood dust. (CalDPH, 2013)

The report notes 23 cases of occupational asthma due to diisocyanate exposure (not due to exposure SPF and not due to exposure MDI/pMDI). This compares to 77 reported cases due to exposure bleach and 50 cases due to exposure to latex, and is on par with the number of cases due to rat allergens. Unfortunately, the report provides no data specific to SPF workers or insulators. The closest the report comes are data for

those products were located. This is not surprising, given that (1) these products are relatively new and the available studies of occupational asthma involving isocyanates all reflect past exposures (*e.g.*, 2009-2012, when these newer products were not in existence), and (2) SPF workers are unlikely to have used only these products and not traditional SPF, making such comparisons impossible.

the categories "heavy and civil engineering construction" and "specialty trade contractors" (CalDPH, 2013), which could clearly be associated with other types of suspected asthmagens (*e.g.*, formaldehyde, glutaraldehyde, and redwood) or other types of isocyanate exposure (*e.g.*, from paint). The occupational asthma case rates in these two groups were 4.1 and 1.2 per 100,000, which is below the rate for other groups, such as hospital workers (12.1 per 100,000 workers). It is also notable that the only occupational group called out in the report for having notable diisocyanate exposure is "molders, shapers, and casters" (CalDPH, 2013), suggestive of individuals in the manufacturing industries. This report is therefore not useful for determining the asthma disease burden among SPF workers in California or elsewhere.

In 2015, the State of Washington published an analysis titled "Work-Related Asthma in Washington State, 2009-2013" that reviewed information concerning 580 cases of work-related asthma occurring from 2009 to 2013 (Washington State Dept. of Labor & Industries., 2015). The total number of workers covered by the surveillance system is not stated, although it does state that "[i]n Washington State, for the years 2006-2009, the prevalence of current asthma in workers was 8.1%" (Washington State Dept. of Labor & Industries, 2015). The authors reported that isocyanate exposure was considered the causative agent in 14 cases (2.4%), but these could be due to various sources of exposure other than SPF. In comparison, "plant material" was noted to be the cause of 68 cases and 63 cases were reported to be associated with mineral and organic dust exposures (Washington State Dept. of Labor & Industries, 2015). Looking by industry, "construction" was associated with 5.5% of asthma cases (Washington State Dept. of Labor & Industries, 2015). This can be compared to "health care and social assistance," the group with the highest occupational asthma rate (19.1%), and "manufacturing," the group with the second-highest occupational asthma rate (13.8%) (Washington State Dept. of Labor & Industries, 2015). There was no mention of SPF or insulation workers in the report. The State of Washington previously published (in 2013) a related report that was specific to isocyanate exposure (Reeb-Whittaker *et al.*, 2013). Using case data reported to the State worker insurance fund, the State identified 27 cases of occupational asthma attributed to isocyanate exposure over an 11-year period (1999 through 2010). The total number of occupational asthma cases due to any cause was reported as 1,469, and the total number of workers reported to be covered by this State worker insurance fund was "approximately 1.9 million" (Reeb-Whittaker *et al.*, 2013). Of the 27 identified cases, only 1 was classified as "drywall and insulation contractors," and was noted to be an "an assistant to an attic insulator" (Reeb-Whittaker *et al.*, 2013). In contrast, the largest fraction of isocyanate-related asthma cases (8) were for "automotive body, paint, and interior repair and maintenance" workers (Reeb-Whittaker *et al.*, 2013). While this study is notable in that it does give information specifically on SPF exposure, it only identifies one case of occupational asthma related to such exposure over an 11-year period. While it is possible to divide that single case by the 1.9 million workers covered in the study to obtain a prevalence rate (*i.e.*, 0.0005%), this seems inadvisable, for the following reasons:

- The goal is to have a prevalence rate among SPF workers, not all workers. The REs are unable to determine how many SPF workers there were in the State of Washington over this time period, because SPF installers are not part of the RE consortium. Moreover, the installation contractor field contains many small companies, so aggregating data among companies about personnel levels 10-20 years ago is impractical.
- A count of one case is likely to produce uncertain extrapolations.

Thus, neither of the Washington State studies is useful for determining the prevalence of occupational asthma among SPF workers, in that state or elsewhere.

Lefkowitz *et al.* (2015) published the results of occupational asthma surveillance activities in multiple states, including California. Their report focused particularly on isocyanate exposure and covered the timeframe 1993 through 2008. The authors reported a total of 44 isocyanate-related occupational asthma cases in California during this 15-year period. Of the 44 California cases, only 8 were clearly associated with MDI exposure and no cases were associated with the use of the Priority Products (*i.e*., SPF containing pMDI). Among construction workers across all four of the states included in the survey, seven cases of isocyanate-related asthma were associated with the category "[s]pecial trade contractors: masonry, stonework, plaster" (which would seem to exclude SPF workers) (Lefkowitz *et al.*, 2015). One case was associated with the category "[h]eavy construction, except building" (also not suggestive of SPF workers/installation), and none were associated with the category "[b]uilding construction–general contractors and operative builders" (Lefkowitz *et al.*, 2015). Thus, again, this study does not provide useful data for estimating asthma prevalence among SPF workers in California or elsewhere.

In addition to the study of Lefkowitz *et al.* (2015), the NIOSH website provides additional data in a series of data tables that represent a later time period than is covered the Lefkowitz *et al.* (2015) study (*i.e.*, 2009 through 2012; NIOSH, 2020). Similar to Lefkowitz *et al.* (2015), NIOSH reports data asthma prevalence for four states, including California (NIOSH, 2020). In these tables, there were zero cases of asthma associated with MDI exposure and five cases associated with exposure to diisocyanates "not otherwise specified (nos)" in California workers from 2009 to 2012 (NIOSH, 2020). Data specifically on the Priority Products are not given. These data do not provide information specifically on SPF workers or installers, the closest being the more generic category "construction laborer" (data reported for all cases of asthma, not isocyanate specific) (NIOSH, 2020). Data on asthma prevalence are also reported by industry, with the closest category to SPF workers/installation being the generic "[s]pecialty trade contractors" (again, for all cases of asthma, not isocyanate specific) (NIOSH, 2020). Such data are not useful in the current evaluation.

Most recently, Syamlal *et al.* (2020) reported that the rate of having an asthma event due to <u>any occupational cause</u> was 8 million in 166 million workers. For construction workers (the most relevant category for SPF workers/installers, but still overly broad), the rate of having "an asthma event" was 221,000 out of 10,500,000 workers (2.1%) (Syamlal *et al.*, 2020). No information regarding exposure to SPF or isocyanates was provided in this study.

Overall, our review of the studies noted above indicates that there is not enough specificity in case numbers or prevalence estimates to define the prevalence of occupational asthma among SPF workers.

Number of SPF Workers

As noted above, Syamlal *et al.* (2020) reported that the rate of having an asthma event was 2.1% among construction workers. Assuming asthma event rates among construction workers generally are similar among SPF workers specifically (a highly questionable assumption, given the differences in materials and personal protective equipment [PPE] that may be used in construction generally *versus* in SPF installation), this rate could be applied to the total number of SPF workers in the State of California to determine the number of occupational asthma cases. No data are available concerning the number of SPF workers in the State of California, but it was suggested by CalDTSC that a national number could be used and then weighted to the relative size of the state and national economies. According to the REs, a generally discussed value in the isocyanate industry is that there are nationwide about 15,000 workers who apply SPF products, although we could identify no basis for this number. CalDTSC also suggested we consult US EPA's TSCA risk evaluation of 1,4-dioxane (US EPA, 2019a). First, US EPA's review of 1,4, dioxane is inappropriate for use in this context, because SPF formulations do not contain 1,4-dioxane, contrary to US EPA's information that a roofing SPF product contains this chemical. Beyond this point, we also believe US EPA's analysis contains faulty assumptions. US EPA appears to have assumed that there are potentially nine sprayers and one non-sprayer on each jobsite where SPF installation is being performed. It is unclear how US EPA developed these numbers; according to the REs, interior SPF application jobs generally have one to two sprayers and one helper, and exterior SPF application jobs may have up to three or four sprayers. US EPA indicates that it used this information, along with the majority of North American Industry Classification System (NAICS) Code 238310 (Drywall and Insulation Contractors) and relevant Standard

Occupational Classification (SOC) codes, to estimate that 162,518 sprayer workers, and 15,627 non-sprayer workers at 17,857 locations are potentially exposed to 1,4-dioxane (US EPA, 2019a). Note that not all the companies listed in these industry codes will install SPF; some may only install other types of insulation. US EPA noted that its values for number of SPF workers potentially exposed to 1,4-dioxane were highly uncertain and were used to provide a bounding estimate only (US EPA, 2019a).

We believe it would be inappropriate to use either the industry nationwide "ballpark" of 15,000 workers or the US EPA estimate of 162,518 workers to calculate asthma rates among SPF workers, for the following reasons:

- The wide disparity between the industry and US EPA estimates is concerning.
- The assumptions US EPA appears to have made in its analysis contradict what is known about how SPF installation companies operate, in terms of the number of workers engaged in installation.
- The lack of a citable reference for the industry value runs counter to the SCP regulations, which stipulate that data used in an AA come from peer-reviewed or government sources.
- Weighting worker numbers by the relative size of the California and national economies is problematic because insulation usage may not track evenly across the country, either due to differences in climate conditions or home construction rates.
- As noted earlier, the rate of asthma in the construction industry may not be indicative of the rate in the SPF industry due to substantial differences in chemicals and PPE used in the general industry *versus* the SPF industry specifically.

Costs for Occupational Asthma Cases

We carried out two types of searches in order to attempt to obtain this information:

- Searches *via* the National Library of Medicine database using the following search terms: "occupational," "asthma," and "cost"; "occupational," "asthma," and "financial"; and "occupational," "asthma," and "expenditures." All search results were examined to determine if they were useful.
- Searches *via* Google using the following search terms: "occupational," "asthma," and "cost." The first 120 search results were examined to determine if they were useful.

The search results indicated that some data are available regarding the costs of treating occupational asthma, both in terms of the cost of treating a single episode as well as data related to the annual costs for occupational asthma treatment. A number of articles provided such information; a few examples are summarized here. For example, Nurmagambetov *et al.* (2018) report that the annual per person incremental medical cost for treating asthma (of any kind) was $3,266. More than 50% of this cost was associated with medication. Leigh *et al.* (2002) estimated that the national costs for treating occupational asthma in the US (including hospital costs, lost wages, fringe benefits, and home production due to disability) totaled $1.6 billion dollars. This was based on the ratio of days spent in the hospital for asthma-related reasons to days spent in the hospital for any reason in the US (1.1 million *vs*. 160 million in 1996) multiplied by cost of all health care in the US ($927 billion in 1996). The authors then assumed that 15% of all asthma cases in the US were due to occupational causes, although the basis for this assumption appears somewhat weak (*i.e.*, "appears to be reliable and widely used in previous analyses" [Leigh *et al.*, 2002]). They also applied a factor to account for indirect costs (lost wages, *etc*.). No specific data were provided for California nor for the SPF industry or isocyanate-exposed workers.

It is worth mentioning the article of Labrecque *et al.* (2011), which reported on the costs of diisocyanate-related asthma in Canadian workers. This article focused on examining the value of isocyanate screening in managing care and reducing costs of compensation for occupational asthma cases. The cost metric involved was the "cost for functional impairment," a financial allocation provided by the government "as a lump sum given at the time the worker is reassessed for disability 2 years after diagnosis and removal from exposure" (Labrecque *et al.*, 2011). The authors reported that the median costs for functional impairment were $C11,900 in screened subjects and $C19,600 in controls (roughly $9,000 and $15,000 USD at the current exchange rates). There are several problems with applying this study to the current evaluation. First, none of the workers evaluated for diisocyanate exposure reported exposure to MDI and most were "body shop workers" (Labrecque *et al.*, 2011), which is unrelated to SPF installation. Second, the cost calculated appears to be a compensation value rather than a cost for medical care; this may be due to the provision of free health care in Canada. Thus, while the title of the article ("Medical Surveillance Programme for Diisocyanate Exposure") suggests that it would have great value for the current exercise, this study does little to help assess the actual cost for treating occupational asthma associated with SPF work.

The 2013 CDPH report mentioned previously also provides some information on the cost of treating asthma in California (without specifics for occupational asthma) (CalDPH, 2013). The report estimated costs of $1 billion in 2010 in California for asthma hospitalizations. The Medicare and Medi-Cal (California Medicaid) programs reportedly covered 65% of the cost of these asthma hospitalizations and 50% of asthma emergency department visits in 2010. The average cost for an asthma hospitalization was estimated at $33,749 in 2010. As noted above, the report stated that over 974,000 people had asthma related to their work, but no specific cost information for these occupational asthma cases was given.

Most recently, Syamlal *et al.* (2020) reported that the annualized average per-person medical expenditures attributable to treating occupational asthma were $901 in general, and $8,238 for cases involving inpatient visits. The authors provided data on the payer (*i.e.*, private insurance, Medicaid, Medicare, out of pocket, other). Interestingly they also provide data by industry, at least broadly. For the construction industry, the category most relevant to SPF workers, the average annual cost was $968 per asthma case and thus similar to the overall value of $901 per case. It is unclear whether the costs of treatment for asthma cases among SPF workers would differ from that for workers in the construction industry in general, and no data were provided that would allow for confident extrapolation from the general construction industry to the SPF industry specifically.

Overall, data on the cost of treating asthma generally as well as occupational asthma specifically are available, although they are somewhat variable. For example, Syamlal *et al.* (2020) reported that the annual cost for inpatient care related to occupational asthma (*i.e.*, in a hospital or other health care facility) was $8,238 (national average), whereas CalDPH (2013) reported the cost for a single asthma-related hospitalization (of any etiology) in California was $33,749. None of the data are specific to the SPF industry, and there may be differences in the level of treatment required for workplace *versus* non-workplace asthma or among asthma cases caused by different asthmagens. Nonetheless, while some values for cost per asthma case are available, the key issue, as noted above, is a lack of data on the number of cases among SPF workers.

Conclusion Regarding Public Health Costs

Overall, insufficient data are available to quantify public health costs for treating occupational asthma associated with MDI/pMDI exposure from the Priority Product. No studies that could be used to quantify the number of occupational asthma cases among workers exposed to the Priority Products were found; studies of occupational asthma exist, but none provide the level of specificity needed for the current evaluation. One study, from the State of Washington (Reeb-Whittaker *et al.*, 2013), does note a single case of occupational asthma in what may be an SPF worker, but extrapolating from a single case to an entire industry would result in a highly uncertain estimate. Data reported specifically for the State of California (CalDPH, 2013; NIOSH, 2020) do not give specific information regarding the SPF workforce. In many of these reports, various occupations associated with occupational asthma are given, but none mention SPF or insulation work specifically. While there are some prevalence estimates for occupational asthma in broad industry categories such as construction, it is likely unreliable to assume these estimates are the same for the SPF industry specifically, due to the potential exposure to other asthmagens and differing levels PPE worn (*e.g.*, carpenters and wood dust, painters and latex paint; may not wear PPE to the extent that SPF workers do).[24] Moreover, estimates of the number of workers in the SPF industry in California are not available with which to translate an occupational asthma prevalence estimate into the number of cases. While some data on the costs of treating asthma are available, the lack of data with which to estimate the number of individuals affected makes it impossible to estimate the total public health costs associated with the Priority Products. This finding aligns with what CalDTSC stated in the technical support document for the Priority Product listing: "The number of people who are sensitized to MDI, and who are a risk of life-threatening asthma attacks from subsequent exposures is unknown" (CalDTSC, 2017b).

Without an estimate of public health costs associated with the Priority Products, estimates of corresponding costs associated with the possible alternatives are not useful. Moreover, determining costs for the "patent alternatives" is not feasible, because many of these products contain respiratory sensitizers (*e.g.*, amine catalysts), and thus, the costs for occupational asthma associated with exposure to these alternatives may not be zero. These products could also be associated with other health problems, but this cannot be known, given that they are not in use, and thus, the potential disease burden information is lacking. The lower-exposure approaches all contain MDI/pMDI and thus have some asthmagenic potential as well. We found no studies that would allow us to distinguish the number of occupational asthma cases associated with these alternatives from the number of cases associated with the use of the Priority Products. This is not surprising given that the possible alternatives have either not been commercialized or have been made available only recently, well after the available studies were conducted.

Thus, after making a *bona fide*, good-faith effort to identify data that could be used to support this portion of the economic analysis, the REs conclude that data are not available to support a credible analysis of the public health costs associated with the Priority Products.

5.4.2.2 Environmental and Waste Management Costs

The SCP regulations require REs to consider the costs of the environmental impacts of a Priority Product and possible alternatives as well as the costs to "governmental agencies and non-profit organizations that manage waste and oversee environmental cleanup and restoration efforts, and/or are charged with protecting natural resources, water quality and wildlife" (22 CCR § 69505.6[a][3]; CalDTSC, 2013).

This requirement is challenging in the context of this AA, and the REs believe that products such as SPF are not what the drafters of the law imagined when they created this provision. This can best be illustrated by using an alternative example that involves two fully commercialized products with distinct chemistries that are well established in the marketplace. In such a case, comparing externalized environmental costs and waste management costs could be accomplished because the impacts, including how those impacts differ between the products, can be known or estimated from details of their production and use.

[24] In its technical support document, CalDTSC stated that "DTSC is particularly concerned about exposures to MDI by sole proprietors and individual consumers who apply SPF through low-pressure systems because they are unlikely to use engineering controls and PPE or industry recommended administrative controls" (CalDTSC, 2017b). In looking through the asthma studies generated by the literature search, we found none that discussed asthma attributable to such DIY-type activities.

In contrast, the situation with the current Priority Products is different. There are a number of "patent alternatives," but these are not yet in the marketplace and involve novel chemistries. It is thus unclear what environmental costs these new chemistries would have or what their waste management requirements would be. Because they are novel chemistries, environmental spill remediation site cleanup costs associated with these chemistries cannot be obtained. The lower-exposure approaches are formulated with MDI, like the current Priority Products (and thus, they are also Priority Products), so the external costs of their environmental impacts (*e.g.*, air emissions from production) should be similar to those of the Priority Products. The only difference would be if the lower-exposure approaches created a different level of waste that had to be managed or had a different likelihood of spills or other environmental contamination from improper use compared to the Priority Products. The REs are unaware of any indication that this is the case. Therefore, a comparison of environmental and waste management costs between the Priority Products and the possible alternatives is not feasible. However, to comply with the SCP regulations to the extent possible, we attempted to identify environmental and waste management costs for the Priority Products.

In order to monetize waste management costs, we would need to determine how much waste Priority Product is disposed of per year. The RE's may have some information on production wastes or off-spec material, but the information Gradient has received from the REs indicates that that there is essentially no waste during the blending of SPF systems. SPF systems have accredited formulas with certain ranges for raw materials. REs can almost always adjust the formula for the B-side to comply with the accredited formula and meet performance requirements (*i.e.*, density, reactivity, dimensional stability, *etc*.). The REs do not manufacture the pMDI used in the Priority Products. Instead, they purchase it from upstream manufacturers. The other significant source of waste from the Priority Products is unused material that may be residual in drums. It is our understanding that applicators are able to use the vast majority of reagents present in product drums for the intended purpose and that furthermore, ACC recommends that residual material that cannot be used for the intended purpose be reacted with B side components to produce non-hazardous construction waste (ACC, 2018). For high-pressure SPF, any unreacted material is manually transferred into new containers. MDI and the B-side resin are not classified as hazardous waste (see Section 7.1.1). For low-pressure SPF, the manufacturers consider the product hazardous waste if it contains a liquid chemical or is under pressure. However, the REs have no knowledge of how much unreacted SPF material containing MDI/pMDI product is disposed of by installers who are not part of the RE consortium. Attempting to estimate how much of the hazardous waste stream in California is composed of unused Priority Product would be highly uncertain, although presumably it is extremely small, given the relative sizes of the SPF and broader chemical and manufacturing sectors.

To see if we could obtain data on costs of environmental management or waste management associated with the Priority Products, we carried out searches *via* Google. The search terms used were:

1. "Isocyanate," "waste management," and "cost";
2. "Isocyanate," "remediation," and "cost";
3. "Spray foam," "waste," and "cost";
4. "Spray foam," "environmental impact," and "cost";
5. "Spray foam," "remediation," and "cost"; and
6. "Spray foam" and "external costs."

We reviewed the first 120 results from each search to see if they were relevant.

The searches primarily provided information on how to manage wastes in general (not just spray foam) and on fees charged by landfills and other facilities for waste disposal (general waste, construction waste). The search of external costs yielded considerable discussion of the need to consider the external costs of heating when examining the cost of installing insulation, but no discussion of the external costs of producing the insulation itself. One significant external cost that was previously associated with SPF was the climate change contribution of the blowing agents (HFCs) used in some SPF applications. However, as the State of California has mandated that low GWP blowing agents be used in these applications instead of HFCs (CARB, 2018a), this external cost is no longer relevant. All new SPF technologies, regardless of formulation or design, will use new lower-GWP blowing agents. The search did not identify any information related to the specific costs of managing unreacted SPF material containing MDI/pMDI or any indications of the costs incurred for remediating spills of such material. We identified no cases of environmental contamination that were specifically associated with accidental spills of Priority Products or any of the possible alternatives.

The REs believe the above constitutes a *bona fide*, good-faith effort to identify data that could be used to support an analysis of environmental and waste management costs as described by the regulation. The REs conclude that data are not available to support an analysis of such costs, either for the Priority Products or any of the alternatives.

5.4.3 Internal Costs

As noted above, the SCP regulation requires REs submitting an AA to evaluate the internal costs of the Priority Product and any alternatives. Internal costs include the costs of equipment and raw materials used to produce products as well as staff costs and other expenditures associated with their development, permitting, production, sales, and management (*i.e.*, training programs). To collect information on internal costs, Gradient consulted a former vice president of a large SPF manufacturer now serving as a consultant to the SFC. The consultant and Gradient developed an internal cost summary providing ranges for various internal costs. The REs have reviewed the internal cost summary and confirmed it is consistent with their typical operations.

This summary of internal costs breaks down the REs into two categories: smaller specialty SPF firms and larger multinational SPF firms. Smaller SPF Specialty Firms are independent SPF systems. Their sales generally range from $10M to $100M. Larger SPF Multinationals are systems houses that are part of larger chemical suppliers. These companies tend to be vertically and horizontally integrated. Their sales generally range from $100M to $500M. Table 5.14 includes a summary of their general internal costs.

Table 5.14 Approximate Internal Costs for SPF Systems Houses

Types of Expenses	Smaller Specialty SPF Firms ($10M to $100M in Annual SPF Sales)		Larger Multinational SPF Firms ($100M to $500M in Annual SPF Sales)	
	Low End	High End	Low End	High End
Raw Material Expenses (55-75%)	$5.5M to $7.5M	$55M to $75M	$55M to $75M	$275M to $375M
Sales and Marketing (5-15%)	$500K to $1.5M	$5M to $15M	$5M to $15M	$25M to $75M
Freight and Warehousing (5-15%)	$500K to $1.5M	$5M to $15M	$5M to $15M	$25M to $75M
Finance and Administration (5-10%)[1]	$500K to $1M	$5M to $10M	$5M to $10M	$25M to $50M
Labor (~2%)	~$200K	~$2M	~$2M	~$10M
Overhead (3-5%)[1]	$300K to $500K	$3M to $5M	$3M to $5M	$15M to $25M
Training and Field Support (3-5%)	$300K to $500K	$3M to $5M	$3M to $5M	$15M to $25M
Codes, QC, and Research (1-3%)	$100K to $300K	$1M to $3M	$1M to $3M	$5M to $15M

Notes:
M = Million, K = Thousands; QC = Quality Control; SPF = Spray Polyurethane Foam.
(1) Overhead generally includes employee benefits, rent, maintenance, utilities, insurance, taxes, legal, office supplies and equipment, and travel expenses.

5.4.3.1 Internal Costs of Developing a New Technology for all SPF Companies

Current business practices for high-pressure SPF systems houses is to have one base chemistry for 0.5-lb, 2-lb, and 3-lb SPF. Developing a new product for one type of SPF or one SPF application is outside of this current model and would significantly impact the economic feasibility of SPF systems houses.

The REs estimate that bringing a new product to market could cost between $735,000 and $1,750,000. This cost is per product. The process would need to be repeated for each application (low-pressure, 0.5-lb, 2-lb, and 3-lb SPF). Table 5.15 outlines predicted costs and a timeline for the research and development process according to the REs.

Table 5.15 Estimated Cost and Time for Research and Development of a New Product

Activity	Estimated Cost	Estimated Time
Research and Development (R&D)	$500,000 to $1,500,000	3 to 5 years
Product Certification Basic Construction (Type V)[1]	$150,000 to $300,000	1 year
Product Certification Basic Construction (Types I-IV)[1]	$50,000 to $300,000	1 year
Annual Listing Fee	$25,000 to $100,000	Not applicable
Other Third-Party Approvals and Certifications[2]	$10,000 to $100,000	Not applicable
Total for R&D	$735,000 to $1,750,000	

Notes:
(1) Once a new product is developed, it takes upwards of $150,000-300,000 to do testing and obtain Evaluation Service listings for its safe use in the field. This provides a basic residential (Type V) listing. For a variety of commercial uses, a further $150,000-300,000 worth of testing and engineering evaluations is required to get approvals for Types I-IV construction.
(2) Other third-party approvals include GREENGUARD, California Department of Public Health (CDPH) Standard Method v1.2, Bureau of Household Goods and Services, and Factory Mutual Approvals.

There may be additional costs are associated with the uncertainty of product research. Not every chemistry or product developed at "bench scale" will be developed into a commercialized product. Research failures could slow down the development process to bring an alternative to market and increase development costs. The REs anticipate that the timeline outlined in Table 5.15 is applicable for chemistries that have been shown to be viable or potentially viable. Further, the REs have a strong understanding of polyurethane chemistry. Developing a new alternative using a fundamentally different chemistry will result in the need to hire new subject matter experts.

Finally, the REs have a robust understanding of the long-term performance of their Priority Products and use that to provide a warranty for their specific products, and there may be significant uncertainty about the long-term performance of any alternative, which could impact product development. This could impact the internal costs associated with developing a new product.

5.4.3.2 Costs of Manufacturing a New Alternative

Several of the alternatives discussed herein would require developing a new specialized manufacturing facility. Manufactures may need to expand their facilities to house additional equipment. It is difficult to predict the cost associated with building additions to existing facilities or purchasing new land and building new manufacturing facilities. Pricing for land and construction varies significantly across the country. After new land is acquired, the REs would need to apply for environmental approvals and permits. According to the REs, these permits can cost between $100,000 and $1,000,000 and take several years to approve, depending on their location and the location's attainment status under the Clean Air Act National Ambient Air Quality Standards (NAAQS).

Other costs associated with retrofitting manufacturing facilities are more predictable. Given that some of the alternatives introduce new chemicals into the REs' raw material portfolio, it would be necessary to for them to purchase and install new storage tanks for bulk materials storage. Costs for purchasing new tanks can range from $50,000 to $150,000 each, depending on the size of the tanks. Based on the formulations outlined in Section 4, the REs could need to purchase up to six new storage tanks each. Manufacturers will also need to purchase metering pumps; pressure, mass, and flow controls; and other automation and safety controls. According to the REs, installing storage tanks can cost from $150,000 to $200,000 per tank, and the total cost of refitting manufacturing equipment is estimated to be at least $1,000,000 to $4,000,000, at the low end of the range. Additional costs could come from the need to have new blending equipment, if it is required to meet demand for a new product, or due to specific requirements for blending new formulations, purchasing new land, building new facilities, and seeking environmental approvals.

Additionally, introducing new chemicals into the REs' manufacturing processes *via* alternative formulations would increase costs associated with raw material transportation, as REs would need to have a significant amount of any new chemicals on-site to produce the new products that require them. Lastly, there may be additional cost for toxicity testing of new products related to chemical registration or importation.

5.4.3.3 Costs to SPF Applicators

Once a product is commercialized, it may be necessary for SPF applicators to update their equipment to handle the physical properties of the new product. According to the REs, related costs to SPF applicator companies are estimated as follows.

- A truck-mounted proportioner and generator costs approximately $100,000-150,000 to fit out.
- Typically, these units can install SPF at 100-150 homes per year, on average.

- Sprayers would have to be re-trained to use new products, at a cost of $1,000-$3,000 per person.
- Applicator companies may need to purchase different types of PPE for their employees to use during SPF installation.
- Industry may need to develop new training programs for applicators.

Note that SPF applicators are not REs; however, this cost was added to provide a more complete picture of the factors included in Priority Product costs.

5.4.3.4 Factors Impacting Commercializing New Products

"Insulation Usage in New Homes and Residential Remodeling, 2020," a report published by Home Innovation Research Labs (2002), estimates that SPF represents a 6.1% market share in the Western US, which it defines as including Alaska, Arizona, California, Colorado, Idaho, Nevada, New Mexico, Montana, Oregon, Utah, Washington, and Wyoming. The REs do not have access to information on the specific SPF market share in California, but believe the percentage reported by Home Innovation Research Labs (2002) for the Western US (6.1%) to be reasonably representative for California. Using this estimate, based on the size of the California SPF market, it is not economically feasible to identify, develop, and commercialize a potential alternative. The SPF market size is not significant enough to make a new alternative product economically feasible, especially if it only provides a solution for a niche application. Commercializing a new product for a niche application would likely come with higher costs and would likely achieve a smaller market size. The non-MDI-based alternative formulations identified are not based on a commodity chemical like pMDI. The use of specialty chemicals that are not manufactured in bulk will increase the cost of any new alternative formulation. Further, REs could be required to pay licensing fees, as these products are patented by individual companies. The REs anticipate that most of the identified potential alternatives could cost manufacturers 2 to 4 times what the Priority Products cost.

5.4.3.5 Conclusions Regarding Internal Costs

From cradle to application, internal costs associated with researching, designing, and developing new manufacturing capacity to bring an alternative product to market could reach over $5M per manufacturer per product. This figure does not represent costs associated with purchasing and developing new manufacturing facilities. As stated above, the REs anticipate that most of the identified potential alternatives could cost manufacturers 2 to 4 times what the Priority Products cost. Given that SPF is already a premium product, it is unlikely that the market would accept a more expensive version of the Priority Products. The REs anticipate that the total SPF market in California is less than $100M. *With 17 REs, the cost to develop a new alternative could easily cost $85M, plus costs associated with developing new manufacturing facilities.* Given the size of the California SPF market, the cost associated with implementing a new alternative, and the fact that monetizing the potential health benefit of any new alternatives is not possible, due to a lack of case numbers of occupational asthma due to SPF exposure in California, implementing a new alternative is not technically or economically feasible.

6 Conclusions of this Abridged AA

6.1 Alternative Analysis Threshold/Acceptable Exposure Reduction

As noted above and in Tables 5.9 and 5.11, there are some potential alternatives that may reduce potential worker exposure to MDI/pMDI. However, because they contain the chemical of concern, and the degree to which exposure must be reduced is not prescribed in the SCP regulations, the acceptability of these alternatives is unclear.

22 CCR § 69501.1(62) defines a "safer alternative" as "an alternative that, in comparison with another product or product manufacturing process, has reduced potential adverse impacts and/or potential exposures associated with one or more Candidate Chemicals, Chemicals of Concern, and/or replacement chemicals, whichever is/are applicable" (CalDTSC, 2013). Section 69505.3 of the regulations allows REs to submit an AAT notification to CalDTSC (CalDTSC, 2013). The notification is made against an AAT "specified" under Section 69503.5(c) by CalDTSC (2013). The AAT is the concentration of a chemical of concern that CalDTSC determines does not meet the prioritization criteria. Under the regulations, only CalDTSC is authorized to "specify" the AAT against which compliance will be measured. The AAT sets an acceptable exposure limit for a chemical of concern.

It is the RE's position that the SCP regulations must be applied in a manner to support adequate notice to REs of their compliance obligations; must be achievable; must be rational; must advance the purposes of the statute; and must not otherwise be arbitrary and capricious. Along those lines, it is clear that if CalDTSC sets an AAT, it must do so in a manner that has the legal and scientific support to deliver a "safer alternative" as that term is defined by statute. This means that the AAT must support a (1) showing of reduced adverse impacts or reduced exposures in a manner that is (2) scientifically justified. A product cannot meet the definition of a "safer alternative" under the statute unless this showing can be reasonably made. It is not sufficient for CalDTSC to propose to regulate on the basis that something "could" be safer; this defeats the purpose of the statute. In other words, to make a positive impact on public health, a potential alternative must have a scientifically demonstrated reduction in adverse impacts (*i.e.*, hazard) and a significant reduction in exposure level.

Substituting one potential hazard for another (or more hazards) or substituting an ingredient for one that only marginally reduces exposure and does not lead to a materially relevant improvement in exposure or adverse impacts to human health and/or the environment for the entire product does not achieve the statutory purposes – and worse, could lead to regrettable substitutions.

When listing the priority product, CalDTSC failed to specify an AAT. Without an AAT, the REs are not equipped with a necessary tool to meaningfully apply the regulations and compare alternatives that may reduce potential adverse impacts or potential exposure to unreacted MDI during SPF application. The REs note that there is a difference with respect to identifying and comparing alternatives that may reduce potential adverse impacts or potential exposure to unreacted MDI during SPF application, *versus* reaching conclusions that the alternatives will reduce impacts or exposures under certain defined conditions – and that those reductions deliver scientifically demonstrated improvements to health/environmental safety such that evidence-based comparison can occur to support a the conclusion that an alternative is safer. Without an AAT, this comparison cannot occur.

The SCP regulations do not allow REs to develop "their own" AATs; they require CalDTSC to make this specification. REs cannot establish their own acceptable exposure limit, in this particular case, for two reasons. First, the REs do not believe that the Priority Product meets the criteria for prioritization (*i.e.*, presenting potential "significant or widespread adverse impacts" and potential exposures) under 22 CCR § 69503.2(a) (CalDTSC, 2013). Second, because the formulae of all the Priority Products vary slightly from one another, in theory, any two SPF products can be compared to identify the one with a lower hazard or exposure profile. This comparison between two products may yield a hazard or an exposure profile difference that is not scientifically supported in a manner that delivers measurable or meaningful reduction in terms of exposure and/or adverse impacts. In this case, the product with the lower hazard or exposure in this head-to-head comparative exercise should not be considered a safer alternative if it fails to significantly reduce adverse impacts and/or exposure. It is insufficient to merely assert that "potential" has been reduced, and it is insufficient to merely demonstrate an exposure difference between two products without demonstrating significant reduction in a manner that translates into measurable human health/environmental improvement. In other words, if a product presenting a hazard is enough to satisfy CalDTSC's prioritization criteria, without CalDTSC developing an AAT, eliminating the hazard entirely is the only way to demonstrate a product has significantly reduced adverse impacts and/or exposure to qualify as a safer alternative. Additionally, it is worth nothing that hazard and exposure are only two of many considerations that need to be taken into account when selecting a potentially safer alternative.

An example of the challenge presented here can be drawn from a benefit-cost analysis or regulatory impact analysis. Consider, for example, a case in which there are three options for proposals to build a road. One is projected to cost $100 million within a band of certainty of plus or minus 5%; the second is projected to cost $100 million and 1 cent within a band of certainty of plus or minus 5%; and the third is projected to cost $101 million within a band of uncertainty of plus or minus 1%. It is clear that for the first two options, one is incrementally less expensive than the other, but only by one penny – which is not a significant or meaningful difference. The two proposals should be considered cost equivalent. The third option might in fact be less expensive when considering the uncertainty band. To understand whether the three proposals are equivalent, or whether one is actually superior, the relative certainty of the projection (and the robustness and completeness of the underlying evidence and models and assumptions made) must also be compared, and these must support the conclusion reached. It is clear that this must be done to support any comparison – otherwise comparisons of "potential" reductions and impact have no basis to support a regulatory decision.

The REs have reviewed the patents for non-commercialized products and health and safety information for lower-exposure approaches that are available on the market (*e.g.*, Firestone/Gaco Profill System and HVLP systems) and made assumptions about the health and safety recommendations based on the potential hazards of ingredients in the non-commercialized potential alternatives (*e.g.*, Firestone/Gaco Canary, NanoSonic HybridSil, Hybrid Coatings Technologies/Nanotech Industries Green Polyurethane, the Owens Corning formulation, the DuPont formulations, the Dow formulation, and the BASF patents). These products still contain hazardous chemicals, and several are still based on pMDI. There is no indication that the use of these products would result in a significant or statutorily meaningful, and supportable, reduction in adverse impacts or exposure. Although Table 5.11 demonstrates that some of these products have a lower emissions profile, the REs do not have the necessary AAT to determine what reduction is materially relevant. Manufacturers of commercialized products are recommending the same level of PPE as the Priority Products to protect applicators from exposure. The REs anticipate that non-commercialized products would still require the same levels of PPE as the Priority Products for use. It is important to note that even if a product might have a slightly lower exposure profile while spraying it, there is still potential exposure during the application process. As CalDTSC has noted, other sources of exposure include spills, opening drums, and misapplication or misuse.

Given the lack of performance information, cost information, and the size of the California market, even having the ability to adequately determine what level of hazard or exposure reduction is appropriate would not have changed the conclusion of this report.

6.2 Need to Identify One Alternative for All SPF Applications

The Priority Product listing includes four types of SPF: low-pressure, high-pressure 0.5-lb, high-pressure 2-lb, and high-pressure 3-lb. It is the REs' position that any safer alternative, as defined by the SCP regulations, would need to replace all of the existing functions of these four types of SPF in a single product type. Implementing a non-MDI-based niche alternative for one application (*i.e.*, open-cell SPF in a wall cavity) or one product (*i.e.*, high-pressure 2-lb SPF) is outside the scope of the REs' business practices. REs that manufacture high-pressure SPF currently produce all three types of high-pressure SPF, and all these applications use pMDI-based polyurethane technology. Implementing a product based on a new chemistry is not technically or economically feasible or in the interest of public health, as discussed below. REs that manufacture low-pressure SPF may have similar issues if an alternative only works for a niche application, but given that those REs only manufacture a single type of Priority Product, the impacts of developing a new alternative may be less severe for them.

The REs have established robust health and safety protocols around the current Priority Product formulations. The hazard of pMDI is well studied, characterized, and managed by the SPF industry. Introducing a new alternative formulation that does not fully eliminate hazardous ingredients, and thus may pose a new hazard, is not in the interest of public health, as discussed in the previous section of this report.

Each identified formulation (both commercialized and not commercialized) is a reactive chemistry built upon ingredients with identified hazards. Developing new products and implementing new protocols for a product that introduces a new hazard to SPF applicators is not technically or economically feasible or in the interest of public health. Substituting one hazard for another would require the REs to develop and implement new worker training protocols or additional PPE. Currently, all SPF workers only need to receive training regarding the proper use of a single type of material – polyurethane foam systems. Introducing a new hazard to the jobsite, by implementing an alternative chemistry, will require retraining workers and special attention to new health and safety protocols for mitigating a new hazard. Complicating worker training may lead to unintended consequences. Further, having multiple products containing different hazards and potentially differing PPE requirements could lead to workers disregarding or misinterpreting safety instructions. Having a single product type for all applications covered by the Priority Product listing is therefore the superior technical option.

Having an alternative that is not based on pMDI implemented for only certain types or applications of the Priority Products is not economically feasible and could adversely complicate product production, requiring additional production facilities or expanding additional facilities (*i.e.*, more land use). The REs estimate that introducing a new chemistry would require additional storage tanks and new processing equipment at current manufacturing facilities. Retooling manufacturing could easily exceed $5M per facility, plus the cost associated with expanding manufacturing facilities and environmental permits. Additionally, introducing new chemicals would increase costs associated with raw material transportation, as REs would need to have more chemicals on-site. Currently, SPF manufacturers reduce costs by using the same raw materials and manufacturing equipment for the high-pressure and low-pressure SPFs currently manufactured. There may also be additional costs for toxicology and other testing to comply with chemical registration requirements. Commercializing a new product for a niche application would likely come with a higher costs, and the market for such an application would likely be smaller. The non-MDI-based alternative formulations are not based on a commodity chemical, like pMDI. The use of specialty chemicals, which are not manufactured in bulk, will increase the cost of any new alternative. Further, the

REs could be required to pay licensing fees, as these alternatives are patented by individual companies. The REs anticipate that most of the identified potential alternatives could come at a price of 2 to 4 times that of the Priority Products, based on professional judgement. As discussed in Section 5.4.3, the REs anticipate that the total SPF market in California is less than $100M. With 17 REs, the cost to develop new alternatives could cost $85M, plus costs associated with developing new facilities. Given the size of the California SPF market, the cost associated with implementing a new alternative, and the fact that none of the identified alternatives make a scientifically demonstrated impact on public health, implementing a new alternative is not technically or economically feasible.

Conducting performance testing to seek building code approvals can cost up to $600,000. These tests need to be repeated for each product brought to the market. To comply with building codes, REs must maintain code approvals. Annually, these code approval reports cost up to $100,000 per product (as discussed in Section 5.4.3). In conclusion, developing, implementing, and holding building code approval for a niche product or a niche application is not economically feasible.

Finally, the REs have already noted that there have been no reported cases of SPF-related asthma in California in the most recent years for which data have been analyzed (NIOSH, 2020), and data from other localities (as presented in the discussion of public health costs – Section 5.4.2) support a very low incidence of occupational asthma due to SPF. Establishing a niche market for an SPF alternative would result in an even smaller potential health benefit than would be obtained from an alternative that replaces all four Priority Product types. Therefore, in terms of improving public health with a technically and economically feasible alternative, any alternative would need be to an alternative to all four of the Priority Product types.

6.3 Potential Alternatives to Priority Products

There are no potentially safer alternatives to the Priority Products that can be appropriately explored in a Stage 2 AA.

Several potential non-MDI-based, sprayable, two-component alternative formulations were identified: Firestone/Gaco Canary, Hybrid Coatings Technologies/Nanotech Industries Green Polyurethane, the Owens Corning formulation, NanoSonic HybridSil, the Dow formulation, and the two DuPont formulations. From the limited information available on these potential alternatives, they all use BPA resins, silicon-based technologies, acetoacetate and organotin catalysts, acrylates, or polycarbamates to replace the unreacted MDI in the Priority Products. However, the ingredient information may be subject to change, because we only identified example formulations in patents rather than actual commercial products. These non-MDI-based alternative formulations still use reactive chemistry, often with hazardous amines as the functional ingredients, resulting in trading one hazardous ingredient for another, a potentially regrettable substitution. According to Table 5.13, only one of the non-MDI-based alternative formulations (Firestone/Gaco Canary) has a slightly lower hazard score (710) compared to generic Group 3 Priority Products (775). The rest of these alternative formulations either score similarly (range of 570-635), higher (910), or substantially higher (1,235) compared to the generic Priority Products (range of 305-775). However, as discussed in Section 6.2, without an AAT, the REs cannot meaningfully compare these reductions in hazard. As previously noted, hazard is just one of many metrics that must be considered in an AA.

The limited available product performance data indicate that none of these non-MDI-based alternative formulations meet all of the required AC 377 standardized SPF performance criteria (Table 5.13). Without a complete set of performance data, we cannot be sure that the formulations described in the patents are viable products. In addition, no product-level exposure potential or emission data could be found for any of these alternative formulations. We attempted to use ingredient-specific physicochemical data to predict ingredient-level exposure potential. As summarized in Table 5.13, the functional ingredients in the Hybrid Coatings Technologies/Nanotech Industries Green Polyurethane patent have lower exposure potential *via* air compared to the functional ingredients in the Priority Products, but no data are available on Green Polyurethane's exposure potential *via* water, soil, or sediment. The rest of the alternative formulations have either similar, higher, or a mix of lower and higher exposure potentials compared to the generic Priority Products. Lastly, it is unlikely that any of the non-MDI-based alternative formulations would be able to replace all three types of high-pressure Priority Products as well as low-pressure Priority Products.

Several potential alternative approaches for product application were also identified. These products or potential products/patents (Gaco/Firestone Profill System; HVLP systems, such as Nitrosys; and two BASF systems) might lower exposure to unreacted MDI from the Priority Products. Gaco/Firestone Profill System relies on a plastic or aluminum barrier for SPF application, whereas the others rely on pre-mixing the ingredients prior to discharge at lower pressure (thus reducing potential exposure). It is not clear whether any of these alternative approaches could replace all three types of high-pressure Priority Products as well as low-pressure Priority Products, and therefore, they are outside of the REs' current business model. From a hazard perspective, none of the lower-exposure approaches is less hazardous than the generic Priority Products. Most have similar hazard scores when compared to their equivalent Priority Product groups (hazards range from 305 to 705 for the lower-exposure approaches compared to 305 to 775 for the generic Priority Products) and one approach (BASF Patent No. WO 2019/089237 A1) has a substantially higher hazard score (1,025) compared to all of the generic Priority Products (range of 305 to 775) (Table 5.13). Two of the lower-exposure approaches (*i.e.*, Profill System and Nitrosys/ICP HandiFoam HVLP MD 2.0) have a complete set of performance data available and meet the AC 377 criteria, which is expected, because they are commercialized Priority Products (Tables 5.10 and 5.13). The other two lower-exposure approaches (*i.e.*, the BASF patents) do not have complete sets of the required performance data per AC 377 (Tables 5.10 and 5.13). Similar to the non-MDI-based alternative formulations, we attempted to use ingredient-specific physicochemical data to predict ingredient-level exposure potential for the lower-exposure approaches. As summarized in Table 5.13, none of the lower-exposure approaches have functional ingredients that have lower exposure potential compared to the generic Priority Products, one alternative approach (Profill System) has higher exposure potential *via* water compared to the generic Priority Products. Lastly, compared to the Priority Products, Profill System would have higher upfront material and labor costs due to the plastic membranes and aluminum channels used for this product. However, increased pre-application labor cost may be offset by the decreased post-application trimming requirements for this product. Whether this rises to the level of a material difference is unclear. Nitrosys/ICP HandiFoam HVLP MD 2.0 would have higher equipment cost compared to the Priority Products due to the separate purchase of the Nitrosys equipment. Nevertheless, it is the REs' position that these products are not safer alternatives. These products are (or would be) Priority Products containing unreacted MDI, and a Priority Product cannot be considered a safer alternative to another Priority Product without an established AAT (*i.e.*, safer exposure level) from CalDTSC. The REs believe having an AAT would not have impacted the outcome of this Abridged AA.

6.3.1 Non-MDI-based Alternative Formulations

Firestone/Gaco Canary™ (Trumbo *et al.*, 2016)

The hazards, relative exposure potential, and performance of the example chemicals in this possible alternative can be assessed and compared to those of the Priority Products, although ideally, such a comparison would involve the actual chemicals found in the marketed product, as composition can change after a patent is filed. Gaco/Firestone confirmed that Canary is not currently commercialized and does not have an SDS. For a product to be commercially viable, it must meet certain criteria, including all technical and performance requirements, price, and the ability to achieve building code compliance. Gaco/Firestone noted that the primary reasons why Canary has not been commercialized are: (a) inability to meet internal processing/manufacturing parameters, (b) inadequate performance in R-value and K-factor per ASTM C518, and (c) shortcomings in passing some code requirements for the product (Table 5.10). Most notably, a solution enabling the material to pass the ASTM E84 burn performance criterion was not found. A decision was made by Firestone/Gaco to cease further efforts in research and development for this product due to the aforementioned technical challenges and the unlikelihood of success.

In addition, this formulation uses HFC-365mfc as a blowing agent (Trumbo *et al*., 2016), which was banned in California on January 1, 2020, for high-pressure SPF products and alternatives, and will be banned in 2021 for low-pressure SPF products and alternatives (CARB, 2018a). Changing to a new blowing agent (*e.g*., an HFO) would likely require significant modifications to the product's formulation and could affect its performance. Lastly, all potential alternatives must conform to local VOC emission limits in California and the additional requirements laid out in the building standards outlined in Section 3.6. No VOC emission data are available for this alternative formulation.

Overall, Canary is not a safer alternative to the Priority Products that can be reliably evaluated in a Stage 2 AA, due to a lack of information about its final formulation and exposure potential, its suboptimal performance on R-value and burn performance criteria, and because it is unlikely to replicate the performance of and serve as a substitute for all three types of high-pressure Priority Products as well as low-pressure Priority Products.

Hybrid Coatings Technologies/Nanotech Industries Green Polyurethane™ (NanoSonic Inc., 2012; Figovsky *et al*., 2015)

For a product to be commercially viable, it must meet certain criteria, including all technical and performance requirements, price, and the ability to achieve building code compliance. Limited data on performance (*e.g*., core density, R-value, compressive strength, and surface burning characteristics) are discussed in the patent for Green Polyurethane, but these data are not supported by testing results, and in most instances, the test performed is not stated (Table 5.10). In addition, all potential alternatives must conform to local VOC emission limits in California and the additional requirements laid out in the building standards outlined in Section 3.6. No VOC emission data are available for this alternative formulation. In summary, Green Polyurethane is not a viable alternative formulation for the Priority Products that can be reliably evaluated in a Stage 2 AA due to the lack of the final formulation, exposure potential information, and a complete set of performance data. In addition, because Hybrid Coatings Technologies and Nanotech Industries are not members of the RE consortium, we were unable to obtain any such information for this product. Additionally, the example functional ingredients provided in the Green Polyurethane patent were somewhat more hazardous than the functional ingredients in the equivalent generic Priority Product group (see Table 5.9). It is also unclear if Green Polyurethane would be able to replicate the performance of and serve as a substitute for all three types of high-pressure Priority Products as well as low-pressure Priority Products.

Note that, per CalDTSC's suggestion, the REs attempted to predict mixture-level physicochemical properties as a proxy for potential product performance or exposure information for the reacted foam using the OECD QSAR Toolbox (OECD, 2020). However, the REs were unable to predict mixture-level physicochemical properties for this potential alternative due the lack of CAS No. for Ancamine 2678, a key functional ingredient described in the Green Polyurethane patent (Figovsky *et al*., 2015).

NanoSonic HybridSil™ (NanoSonic Inc., 2012, 2013)

Ultimately, no information is available on HybridSil's ingredients, exposure potential, and performance with which to assess whether this product will serve as a safer alternative to the Priority Products. Because NanoSonic is not part of the RE consortium, we were unable to obtain any such information for this product. HybridSil is therefore not a safer alternative to the Priority Products that can be further considered in a Stage 2 AA. Additionally, it is unclear if HybridSil would be able to replicate the performance of and serve as a substitute for all three types of high-pressure Priority Products as well as low-pressure Priority Products.

Owens Corning Formulation (Olang, 2012)

The hazards and relative exposure potential of the example chemicals in this alternative formulation can be assessed and compared to those of the Priority Products, although ideally such a comparison would involve the actual chemicals found in the marketed product, as composition can change after a patent is filed. Overall, the Owens Corning formulation is not a safer alternative to the Priority Products that can be further considered in a Stage 2 AA. Limited data on the formulation's performance (*e.g.*, R-value range, estimated reaction time) are discussed in its patent (but are not supported by provided test results) (Table 5.10); other critical product information is missing (*e.g.*, anticipated density, compressive and tensile strength, flame spread resistance). Because Owens Corning is not part of the RE consortium, we were unable to obtain any such information for this alternative. In addition, all potential alternatives must conform to local VOC emission limits in California and the additional requirements laid out in the building standards outlined in Section 3.6. No VOC data is available for this alternative formulation. A hazard review of the example functional ingredients provided in the Owens Corning formulation patent found that the ingredients were substantially more hazardous than the functional ingredients in the equivalent generic Priority Product group (see Section 5.1). Additionally, it is unclear if the technologies described in this patent would be able to replicate the performance of and serve as a substitute for all three types of high-pressure Priority Products as well as low-pressure Priority Products.

DuPont Formulations: Patent No. WO 2013/101682 A1 (Jin *et al.*, 2013) and Patent No. WO 2018/005142 A1 (Thomas *et al.*, 2018)

For a product to be commercially viable, it must meet certain criteria, including technical viability, price, performance, and code compliance. According to communications with DuPont, the two DuPont patents failed to meet one or more of these criteria, as described below.

- The primary reason the technology described in the 2013 carbon-Michael chemistry patent (Patent No. WO 2013/101682 A1; Jin *et al.*, 2013) was not commercialized was due to lack of a working catalyst to meet performance requirements for the product. The technology was able to yield a foam that had certain required properties, such as dimensional stability. However, there were significant deficiencies, including reaction times that are too long, poor shelf life (<2 months), and toxicity concerns. These deficiencies made this formulation non-viable as a commercial product, and it was not taken to market. A decision within DuPont was taken to cease further research and development on this product due to the aforementioned insurmountable technical challenges, which could not be solved after a multi-year research program, and the unlikelihood of success if further pursued.
- The primary reason the technology described in the 2018 aminal chemistry patent (Patent No. WO 2018/005142 A1; Thomas *et al.*, 2018) was not commercialized was the inability to meet the dimensional stability requirements as defined by code AC 377 (ICC-ES, 2018). Furthermore, it was not hydrolytically stable (degrades in the presence of heat and moisture), which, given the

typical ambient moisture seen in the buildings in which the product is intended to be used, makes it non-viable. The formulation was so unstable that DuPont was not able to run typical physical property tests or to spray the created foams; thus, all the work on the formulation was done as "cup" chemistry on the bench. These deficiencies made this technology non-viable as a commercial product, and it was not taken to market. A decision within DuPont was taken to cease further research and development on this technology due to the aforementioned insurmountable technical challenges, which could not be solved after a multi-year research program, and the unlikelihood of success if further pursued.

Additionally, both of these patents were filed with HFC blowing agents, which were banned in California on January 1, 2020, for high-pressure SPF products and alternatives, and will be banned in 2021 for low-pressure SPF products and alternatives (CARB, 2018a), making the formulation unable to be considered in the current regulatory environment in California.

Both of the DuPont patents are not safer alternatives to the Priority Products due to the lack of a final formulation, exposure potential information, and sub-optimal performance on multiple AC 377 criteria (Table 5.10). While our hazard evaluation of the example ingredients provided in the patents resulted in similar hazard scores between the DuPont patents and the generic Priority Products, DuPont has expressed concern over the potential toxicity of Patent No. WO 2013/101682 A1, which could be due to test data, change in formulation, *etc*. Additionally, it is unlikely that the technologies described in these patents would be able to replicate the performance of and serve as a substitute for three types of high-pressure Priority Products as well as low-pressure Priority Products.

Dow Formulation (Foley *et al*., 2015)

The formulation described in Dow Patent No. WO 2015/142564 A1 is not a safer alternative for the Priority Products due to the lack of a final formulation, exposure potential information, and the full suite of required performance data. Because Dow is not part of the RE consortium, we were unable to obtain any such information for this alternative. The patent also describes a water-soluble foam that can lose up to 24% weight in tests, which is problematic because any safer alternative would need to provide similar moisture resistance and structural support compared to that of the Priority Products. Our hazard evaluation of the example ingredients provided in the patent resulted in similar hazard scores between the formulation provided in the patent and the generic Priority Products. An analysis of the ingredient-exposure potential also revealed potential higher exposure potential *via* air for the formulation described in the patent compared to the ingredients in the generic Priority Products. Additionally, it is unclear if the technologies described in this patent would be able to replicate the performance of and serve as a substitute for all three types of high-pressure Priority Products as well as low-pressure Priority Products.

6.3.2 Lower-Exposure Approaches

Firestone/Gaco Profill System™ (Gaco Western, 2017b, 2020)

Profill System is not a safer alternative in the context of this Abridged AA. While MDI emission is lower with the Profill System, its hazard score (305) is equal to that of other open-cell, 0.5-lb Priority Products (*i.e*., Profill System's comparable Priority Product group). It is worth repeating that the formulation used in Profill System was specially formulated so that the foam does not rupture the membranes, which would occur with traditional SPF formulations. Due to the lack of an established AAT, the REs cannot adequately determine what constitutes a material difference in hazard and exposure reduction. Profill System is not a safer alternative because the hazard associated with its use is not lower than that associated with the use of the Priority Products, it uses the chemical of concern (*i.e*., unreacted MDI), and its use still requires that workers wear PPE. Additionally, Profill System could not serve as a substitute for all three types of high-pressure Priority Products as well as low-pressure Priority Products.

HVLP Systems (*e.g.*, Nitrosys/ICP HandiFoam® HVLP MD 2.0; ICP Building Solutions Group, 2019a,b)

HVLP systems are not a safer alternative in the context of this Abridged AA. The hazard score for this type of SPF product (705) is equal to that of other closed-cell, 2-lb Priority Products (*i.e.*, HVLP systems' comparable Priority Product group). MDI emission was also similar between an example HVLP system (*i.e.*, Nitrosys/ICP HandiFoam HVLP MD 2.0) and the comparable Priority Product group. Due to the lack of an established AAT, the REs cannot adequately determine what constitutes a material difference in hazard and exposure reduction. HVLP systems are not a safer alternative because the hazard associated with their use is not lower than that associated with the use of the Priority Products, they use the chemical of concern (*i.e.*, unreacted MDI), and their use still requires that workers wear PPE. Additionally, HVLP systems could not replace all three types of high-pressure Priority Products as well as low-pressure Priority Products.

BASF Patent No. 9592516 B2 (Wishneski *et al.*, 2017)

The technology described in this patent is not a safer alternative in the context of this Abridged AA. For a product to be commercially viable, it must meet certain criteria, including technical viability, price, performance, and code compliance. According to BASF, the technology described in this patent has not yet been commercialized due to its inability to meet one or more of these parameters for a specific SPF application. However, further research and development work on the technology is ongoing. No SDS is available for the technology described in this patent.

In terms of ingredient hazards, the hazard score (560) for the example formulation described in the patent is similar to that of the Group 2 (305-540) and 3 (775) Priority Products (*i.e.*, the comparable Priority Product groups). While MDI emission information was reported in this patent, no comparable MDI emission data from similar study protocols are available. This patent does not offer the complete set of performance data required for a commercialized Priority Product. Due to the lack of an established AAT, the REs cannot adequately determine what constitutes a material difference in hazard and exposure reduction. In other words, the technology described in this patent is not a safer alternative to the Priority Products because the hazard associated with its use is not lower than that associated with the use of the Priority Products, it uses the chemical of concern (*i.e.*, unreacted MDI), and its use would still require that workers wear PPE. There is also no available information about the products' final formulation or exposure potential, and only limited available performance data (Table 5.10). Additionally, the technology described in this patent could not replace all three types of high-pressure Priority Products as well as low-pressure Priority Products.

BASF Patent No. WO 2019/089237 A1 (Wishneski *et al.*, 2019)

The technology described in this patent is not a safer alternative in the context of this Abridged AA. For a product to be commercially viable, it must meet certain criteria including technical viability, price, performance, and code compliance. According to BASF, the technology described in this patent has not yet been commercialized due to its inability to meet one or more of these parameters for a specific SPF application. However, further research and development work on the technology is ongoing. No SDS is available for the technology described in this patent.

This formulation also contains at least one California Candidate Chemical (*i.e.*, MDI, CAS No. 101-68-8) (CalDTSC, 2019a). Its hazard score (1,025) is substantially higher compared to any of the Priority Product groups (range: 305 to 775). While MDI emission information was reported in this patent, the emission was lower, similar, and higher compared to the generic Priority Products (Groups 1 2, and 3, respectively). We compared its emission data to those of all three of the Priority Product groups with such data due to inadequate information available to allow for assigning a product grouping for the technology described in this patent. Due to the lack of an established AAT, the REs also cannot adequately determine what constitutes a material difference in hazard. The technology described in this patent is not a safer alternative to the Priority Products, because a hazard review of the example functional ingredients found the ingredients to be substantially more hazardous than the functional ingredients in the generic Priority Products. In addition, it uses the chemical of concern (*i.e.*, unreacted MDI), and its use would still require that workers wear PPE. There is also no available information about the product's final formulation or exposure potential, and no available performance data. Additionally, the technology described in this patent could not replace all three types of high-pressure Priority Products as well as low-pressure Priority Products.

Lastly, on internal cost, 22 CCR 69505.5(a)(3)(B) (CalDTSC, 2013) requires the REs to fully explain their rationale, in full AA reports, if a decision to retain the Priority Product is justified in part or solely on the basis of internal cost. The decision to conduct an Abridged AA was not based solely on internal cost, but rather, the lack of information on the performance of several alternatives, the fact that none of the alternatives outperformed the Priority Products, and the similar hazard profile of the potential alternatives and the Priority Products. However, the REs believe that the potential internal costs of upwards of $85M to develop a new alternative do not justify selecting an alternative to the Priority Products.

6.4 Decision Concerning an Abridged AA or Stage 2 AA

The conclusion of this Abridged AA is that there are no alternatives to the Priority Products with sufficient data to support an accurate full AA according to the SCP regulations' requirements. A proposed research and development plan to seek and make available a safer product to replace the Priority Products is outlined in Section 7.

7 Implementation Plan

There are a number of potential regulatory responses CalDTSC may take following the submission of a Stage 1 or Abridged AA (CalDTSC, 2019b). These include CalDTSC requiring or imposing:

- Supplemental AA Report Information and Regulatory Response Revisions;
- Product Information for Consumers;
- Use Restrictions;
- Product Sales Prohibition;
- Engineering or Administrative Controls;
- End-of-Life Product Management Program;
- Advancement of Green Chemistry and Green Engineering; or
- No Regulatory Response. (CalDTSC, 2019b)

A number of these potential regulatory responses are already in place for the Priority Products (*i.e.*, engineering or administrative controls, use restrictions, and product information for consumers). Table 7.1 outlines which requirements under "Product Information for Consumers" are already in place for high- and low-pressure SPF.

SPF products are extremely effective at providing insulation, air and moisture sealing, and energy conservation at a reasonable price. Further use restrictions or product sales prohibitions would significantly affect commercial buildings and residential homes' energy efficiency and lead to increased greenhouse gas emissions, due to increased heating and cooling needs, thus impeding the achievement of some of California's climate change goals.

Under the SCP regulations, an AA must address, at a minimum, two potential regulatory responses: provision of product information for consumers, as defined under 22 CCR § 69506.3, and a proposal for a research and development project to make a safer product available (CalDTSC, 2013, 2017a).

7.1 Product Information for Consumers

As part of the SCP regulations, 22 CCR § 69506.3 requires manufacturers to disclose certain information to consumers, including commercial and retail purchasers. There is significant overlap between the information required by 22 CCR § 69506.3 (CalDTSC, 2013), the OSHA HCS (29 CFR §1910.1200; OSHA, 2017), and the FHSA (16 CFR § 1500; US CPSC, 2017). Table 7.1 outlines this overlap. The OSHA HCS sets requirements for labels and SDSs for products used in professional settings, such as high-pressure and low-pressure SPF. The FHSA sets requirements such as labeling for products that are available *via* retail sources, such as low-pressure SPF. The Fair Packaging and Labeling Act (FPLA) sets requirements, such as labeling, for consumer commodities (Federal Trade Commission, 2002). As detailed in Table 7.1, labels for SPF products already provide adequate hazard warnings.

Table 7.1 Overlap Between 22 CCR § 69506.3, 29 CFR § 1910.1200, and 16 CFR § 1500

Information Requirements from 22 CCR § 69506.3	CalDTSC (2013) Citation	OSHA (2017) HCS Label Requirement Citation	OSHA HCS SDS Requirement Citation	Federal Hazardous Substances Act (FHSA) Citation (US CPSC, 2017)
		High-Pressure and Low-Pressure SPF	High-Pressure and Low-Pressure SPF	Low-Pressure SPF
"Manufacturer's name and importer's name, and/or the name of any other entity listed on the product label."	22 CCR § 69506.3(b)(1)	29 CFR § 1910.1200(f)(1)(vi)	29 CFR § 1910.1200(g)(2)(i)	16 CFR § 1500.121(a)(1)
"Brand name(s) and product name(s), and a description of the product."	22 CCR § 69506.3(b)(2)	29 CFR § 1910.1200(f)(1)(i) Also required by FPLA (16 CFR Part 500)[1]	29 CFR § 1910.1200(g)(2)(i)	Not required on FHSA labels Required by FPLA (16 CFR Part 500)[1]
"A list of, and common names for, any Chemical(s) of Concern that remain in the product and/or any replacement Candidate Chemical(s) and known hazards traits and/or environmental or toxicological endpoints for those chemicals, based on available information."	22 CCR § 69506.3(b)(3)	29 CFR § 1910.1200(f)(1)(i); 29 CFR §1910.1200(f)(1)(ii); 29 CFR §1910.1200(f)(1)(iii); 29 CFR §1910.1200(f)(1)(v)	29 CFR § 1910.1200(g)(2)(ii); 29 CFR § 1910.1200(g)(2)(iii); 29 CFR § 1910.1200(g)(2)(ix); 29 CFR § 1910.1200(g)(2)(x); 29 CFR § 1910.1200(g)(2)(xi); 29 CFR § 1910.1200(g)(2)(xii);	16 CFR § 1500.121(a)(1)
"A statement informing consumers that the product must be disposed of or otherwise managed as a hazardous waste at the end of its useful life, if applicable."	22 CCR § 69506.3(b)(4)	29 CFR § 1910.1200(f)(1)(v) SDS must include the following statement: "Dispose of contents/ container to accordance with local/regional/national/ international regulations."	29 CFR 1910.1200(g)(2)(ii): Section 2 of the SDSs must include precautionary statements, including statements related to product disposal. 29 CFR § 1910.1200(g)(2)(xiii): Section is not mandated to be completed by OSHA HCS.	Not required by FHSA

Information Requirements from 22 CCR § 69506.3	CalDTSC (2013) Citation	OSHA (2017) HCS Label Requirement Citation	OSHA HCS SDS Requirement Citation	Federal Hazardous Substances Act (FHSA) Citation (US CPSC, 2017)
		High-Pressure and Low-Pressure SPF	High-Pressure and Low-Pressure SPF	Low-Pressure SPF
"Any safe handling and storage procedures and/or other information needed to protect public health or the environment during the useful life of the product, including precautions that consumers may take to prevent or limit exposure to the Chemical(s) of Concern or replacement Candidate Chemical(s), and first aid and accidental release procedures."	22 CCR § 69506.3(b)(5)	29 CFR § 1910.1200(f)(1)(iii); 29 CFR § 1910.1200(f)(1)(iv); 29 CFR § 1910.1200(f)(1)(v)	29 CFR § 1910.1200(g)(2)(iv); 29 CFR § 1910.1200(g)(2)(v); 29 CFR § 1910.1200(g)(2)(vi) 29 CFR § 1910.1200(g)(2)(vii); 29 CFR § 1910.1200(g)(2)(viii)	16 CFR § 1500. 121(a)(1)
"Identification of any end-of-life management requirements specified by law, and any existing end-of-life management program(s) for the product."	22 CCR § 69506.3(b)(6)	Not required by OSHA HCS There are no end-of-life management requirements for the Priority Products.	Not required by OSHA HCS There are no end-of-life management requirements for the Priority Products.	Not required by FHSA There are no end-of-life management requirements for the Priority Products.
"The manufacturer's website address and the importer's website address where the consumer can obtain additional information about the product, the adverse impacts associated with the product as identified in the AA Report for the product, and proper end-of-life disposal or management of the product."	22 CCR § 69506.3(b)(7)	Not required by OSHA HCS	Not required by OSHA HCS	Not required by FHSA

Notes:
AA = Alternatives Analysis; CCR = Code of California Regulations; FPLA = Fair Packaging and Labeling Act; HCS = Hazard Communication Standard; OSHA = Occupational Safety and Health Administration; SDS = Safety Data Sheet; SPF = Spray Polyurethane Foam.
(1) All packaging for products sold in the US must have three these items (in addition to the other environmental health and safety requirements) per federal US law. (1) a statement identifying the product; (2) the name and place of business of the manufacturer, packer, or distributor; and (3) the net contents of the product package in metric and English units (weight, measure, or numerical count) (Federal Trade Commission, 2002).

7.1.1 Product Information for Consumers – High-Pressure SPF

High-pressure SPF systems are not a traditional consumer product in that only professional SPF installers are able to source and install these systems. However, SPF applicators are viewed as "consumers" under the SCP regulations (22 CCR § 69506.3; CalDTSC, 2013). Conversely, the OSHA HCS (29 CFR §1910.1200; OSHA, 2017) classifies SPF applicators as workers. Therefore, most of the information required under 22 CCR § 69506.3 is required to be provided to SPF applicators, under the OSHA HCS product label and SDS requirements. As for 22 CCR § 69506.3(c), manufacturers of high-pressure SPF already have to provide labels with their respective products according to 29 CFR § 1910.1200. Product SDSs are also available on or can be accessed from the manufacturer's website. The SDS have the necessary information to comply with 22 CCR § 69506.3 (CalDTSC, 2013).

- **Manufacturers Name (22 CCR § 69506.3(b)(1)):** Covered by the OSHA HCS.
- **Brand Name and Description of Product (22 CCR § 69506.3(b)(2)):** Covered by the OSHA HCS and FPLA (Federal Trade Commission, 2002).
- **Name of Chemical of Concern (22 CCR § 69506.3(b)(3)):** Covered by the OSHA HCS.
- **Hazard Waste (22 CCR § 69506.3(b)(4)):** A material is considered a hazardous waste if (1) it is a hazardous waste listed by US EPA in 40 CFR Part 261, Subpart D, or (2) exhibits at least one of the four characteristics defined in 40 CFR 261, Subpart C. The four characteristics are ignitability, corrosivity, reactivity, and toxicity. pMDI is not considered hazardous wasted under the Resource Conservation and Recovery Act (RCRA). Although, California's hazardous waste regulations are slightly more rigorous, pMDI is not classified as hazardous waste in California. Used A-side material is manually transferred by emptying the remaining contents into a new A-side drum. Used A-side containers are considered empty when less than 1 inch of residue remains on the bottom of the container or inner liner (ACC, 2018). The empty drums are then sent for processing.

  CalDTSC's Priority Product listing only identified concerns with the A-side of the product. It is worth noting that the B-side of the product is not considered hazardous waste, and remaining contents from the B-side are also manually transferred into a new B-side drum.
- **Safe Handling Instructions (22 CCR § 69506.3(b)(5)):** Covered by the OSHA HCS.
- **End-of-Life Management (22 CCR § 69506.3(b)(6)):** The Priority Products do not have any end-of-life management requirements in California; therefore, 22 CCR § 69506.3(b)(6) is not applicable.
- **Manufacturer's Website (22 CCR § 69506.3(b)(7)):** In practice, most REs include their website on product labels and SDSs. Some REs may need to update product labels or SDSs for the A-side to address 22 CCR § 69506.3(b)(7).
- **Applicator Training:** To improve product stewardship practices, SPF manufacturers propose to include a statement on product labels or bunghole covers to state that users must either (1) take the free online CPI Spray Polyurethane Foam Chemical Health and Safety Training available at www.spraypolyurethane.org before opening the product or (2) have successfully passed the manufacturer's installer training. The free online Spray Polyurethane Foam Chemical Health and Safety Training (available in English and Spanish) provides information for SPF contractors, applicators, and helpers about the use, handling, and disposal of SPF; potential health hazards; and control measures, including engineering controls and PPE. The training addresses issues with the A- and B-sides of the product. The REs note that mandating applicator training under the SCP regulations shifts the regulatory response requirements from the REs to the product users. Given that the product is not always sold directly to the applicator, the REs cannot fully implement a

mandatory training program. In addition to the online CPI Spray Polyurethane Foam Chemical Health and Safety Training, various REs have developed and implemented in-person worker training programs and other voluntary product stewardship tools.

- High-pressure SPF manufacturers will need 6 months to update SDSs and 12 months to update labels after CalDTSC finalizes the rule to implement the "Product Information for Consumers" regulatory response.

7.1.2 Product Information for Consumers – Low-Pressure SPF

Low-pressure SPF systems are generally not marketed for consumer use. However, due to the nature of the product, consumers as well as professional users may use the product. Accordingly, low-pressure SPF manufacturers label the product according to the OSHA HCS and the FHSA (OSHA, 2017; US CPSC, 2017). Some manufacturers use a blended label, while some products have one label for each standard. Therefore, most of the information required under 22 CCR § 69506.3 is required to be provided to SPF applicators under the OSHA HCS product label and SDS requirements, and to consumers under the FHSA label requirements. As for 22 CCR § 69506.3(c), manufacturers of low-pressure SPF already have to provide labels with their respective products according to 29 CFR § 1910.1200 and 16 CFR §1500 (OSHA, 2017; US CPSC, 2017). Product SDSs are also available on or can be accessed from the manufacturer's website. The SDSs have the necessary information to comply with 22 CCR § 69506.3.

- **Manufacturers Name (22 CCR § 69506.3(b)(1)):** Covered by the OSHA HCS and FHSA.
- **Brand Name and Description of Product (22 CCR § 69506.3(b)(2)):** Covered by the OSHA HCS and FPLA (Federal Trade Commission, 2002).
- **Name of Chemical of Concern (22 CCR § 69506.3(b)(3)):** Covered by the OSHA HCS and FHSA.
- **Hazard Waste (22 CCR § 69506.3(b)(4)):** pMDI is not classified as hazardous waste by California or RCRA. However, manufacturers consider the product to be hazardous waste if the product container is not empty and still under pressure. The OSHA HCS regulations require the product label to provide disposal statements. The required precautionary statement for disposal for potential respiratory sensitizers is "Dispose of contents/container in accordance with local/regional/national/international regulations" (OSHA, 2017). Low-pressure SPF manufacturers believe this statement should satisfy 22 CCR § 69506.3(b)(4).
- **Safe Handling Instructions (22 CCR § 69506.3(b)(5)):** Covered by the OSHA HCS and FHSA.
- **End-of-Life Management (22 CCR § 69506.3(b)(6)):** The Priority Products do not have any end-of-life management requirements in California; therefore, 22 CCR § 69506.3(b)(6) is not applicable.
- **Manufacturer's website (22 CCR § 69506.3(b)(7)):** In practice, most REs include their website on product labels and SDSs. Some REs many need to update product labels or SDSs to address 22 CCR § 69506.3(b)(7).
- **Applicator Training:** To improve product stewardship practices, low-pressure SPF manufacturers propose to include a statement on product labels or on a tag adhered to the product application equipment that must be removed prior to use that states that users must either (1) take the free online CPI Spray Polyurethane Foam Chemical Health and Safety Training available at www.spraypolyurethane.com or (2) have successfully passed the manufacturer's installer training. The free online Spray Polyurethane Foam Chemical Health and Safety Training (available in English and Spanish) provides information for SPF contractors, applicators, and helpers about the

use, handling, and disposal of SPF; potential health hazards; and control measures, including engineering controls and PPE. The training addresses health and safety concerns with the A- and B-sides of the product. The REs note that mandating applicator training under the SCP regulations shifts the regulatory response requirements from the REs to the product users. Given that the product is not always sold directly to the applicator, the REs cannot fully implement a mandatory training program. In addition to the online CPI Spray Polyurethane Foam Chemical Health and Safety Training, various REs have developed and implemented worker training programs and other voluntary product stewardship tools.

- Low-pressure SPF manufacturers will need 6 months to update SDSs and 12 months to update labels after CalDTSC finalizes the rule to implement the "Product Information for Consumers" regulatory response.

7.2 Proposed Potential Research and Development Plan

The "Advancement of Green Chemistry and Green Engineering" regulatory response (22 CCR § 69506.8) requires REs to fund a research program to:

(a) Design a safer alternative to the Priority Product;
(b) Improve the performance of a safer alternative to the Priority Product;
(c) Decrease the cost of the safer alternative to the Priority Product; and/or
(d) Increase the market penetration of a safer alternative to the Priority Product. (CalDTSC, 2013)

The SPF industry has concluded that a functionally acceptable and technically feasible alternative to low-pressure Priority Products or for high-pressure open-cell, closed-cell, or roofing Priority Products is not available. Therefore, the REs believe that Options B, C, and D are not suitable for a research program.

Within 12 months of CalDTSC approving the Abridged AA report, SFC and CalDTSC will agree to a mutually acceptable research project.

8 Uncertainty Analysis

A number of possible sources of uncertainty were encountered in the course of conducting this Abridged AA. The key sources are summarized below.

Identification of Potential Alternatives. Alternatives were identified based on patent searches, general Internet searches, and conversations with the REs. It is possible that other non-MDI-based alternative formulations exist and were not identified, but this is considered unlikely given that the AA was directed by a large number of REs with great familiarity with the industry. For any alternative that could have been missed (*e.g.*, an obscure patent, possibly not in English), one would need to have data on the product's chemical composition, hazards, exposure, and performance in order for it to have had a significant impact on the conclusions of this Abridged AA. Given that the patents that were examined lacked sufficient data to support a Stage 2 AA, it would not be expected that any patent missed would have such information. Thus, the conclusions of this Abridged AA would not change.

Evaluation of Relevant Factors. As noted earlier, the non-MDI-based alternative formulation patents provide fairly broad discussions of product composition (*e.g.*, classes of chemicals, rather than specific chemicals). The Abridged AA attempted to assess these potential alternatives based on the provided example formulations, but there is no guarantee that these would be the final components of any commercialized versions of the products. As a result, there is uncertainty in the determination of whether certain factors spelled out in the SCP regulations are materially different among the alternatives (notably, some of the health effect endpoints). The conclusion of this Abridged AA is that there are no safer alternatives to the Priority Products, largely due to a lack of data to support a full assessment and the lack of specific and definitive composition data in the patents describing many of the potential alternatives.

Grouping of Products. Because there are over 170 different SPF products covered by this Abridged AA, we assigned product groupings for Priority Products and alternatives based on density and pressure, to streamline the analysis and facilitate comparisons. As a result, there may be some minor differences in hazard and product exposure between the Priority Products in the same group. These minor differences are not covered in this Abridged AA.

Hazard Evaluation. To evaluate the hazards of the alternatives, we primarily relied on ECHA REACH dossiers and Pharos. We did not conduct an exhaustive literature review on each chemical of interest. Had we done so, we may have uncovered additional hazard data that could conflict with the data in the aforementioned sources or that could fill in data gaps. This detailed evaluation of health hazard data would have been conducted during Stage 2 of the AA process. Moreover, as noted above, the composition information we had on the non-MDI-based alternative formulations was for exemplar formulations, which may not reflect the composition of any actual commercial product. Thus, a detailed toxicological review of the exemplar formulae provided in the alternative formulations' patents is not practical or additive to this AA. Additionally, we could not identify hazard or physicochemical information for seven ingredients, due to their generic chemical names and alack of CAS Nos for them. These ingredients are the polymers in generic polyester polyol, sucrose acetoacetate, glycerin acetoacetate, Ancamine 2678, polycarbamate, polycarbamate 2, and Terol 258. Some of these ingredients may not have CAS Nos. (*e.g.*, polymer in generic polyester polyol, polycarbamate).

Hazards of Constituents *versus* Final Products. Hazards and physiochemical data were evaluated for the functional ingredients of the Priority Products and potential alternatives. Data were generally lacking for the final products. Data are certainly lacking for the non-MDI-based alternative formulations. As a result, the hazards shown in Tables 5.2-5.4 do not necessarily reflect the hazards of the final products (*i.e.*, cured foam). This could lead to an inappropriate comparison, as we have noted in Section 5.

Use of CSI-Like Hazard Scoring Approach and Penalizing for Data Gaps. We adapted the CSI approach to provide quantitative scores of hazard endpoints (Tables 5.6-5.8), but note that these scores should only be used as approximations of hazards, due to the underlying uncertainties. Although we largely retained the scoring values provided in the original CSI method, which was published in a peer-reviewed journal (Verslycke *et al*., 2014), we also needed to make certain modifications to the approach meet the requirements of the SCP regulations. See Section 5.1.2 for a full description of these modifications. As a sensitivity analysis, we reperformed the scoring analysis using two hypothetical scenarios: (1) assigning the maximum penalty score for data gaps regardless of what percentage of the product composition was accounted for by chemicals with data gaps, and (2) using no penalty scores for data gaps. In both cases, we always evaluated products in which >30% of the composition was accounted for by chemicals with no data. In both scenarios, the relationships between the Priority Products and possible alternatives remained the same. Additionally, one could argue that the polyester polyol polymer in the generic Priority Products would have no or low human health and aquatic toxicity, due to the presumed large molecular size. However, no information was available on the CAS No. or molecular weight of this ingredient to substantiate this professional judgment. As a result, the polyester polyol polymer in the Priority Products was given data gap penalty scores, rather than scores of 0 for presumed no or low hazard.

Performance. As noted earlier, we lacked data to fully assess the performance of some of the non-MDI-based alternative formulations, because these do not appear to have progressed sufficiently in development to have been subjected to all of the required tests. It is possible that if such data were available, we could have reached more definitive opinions on relative performance compared to the Priority Products. However, that scenario requires data that do not exist, and the SCP regulations specifically do not require the generation of new data.

Exposure/Emission. No comparable product-level emission data using the same study protocol are available for the generic Priority Products or lower-exposure approaches. The protocols differed in terms of test methods, ventilation, sampling time points, *etc*. While an attempt to compare product-level emission data was made in Table 5.11, direct comparisons of all the emission data would be inappropriate.

Approximate Product Cost. In response to comments from CalDTSC, approximate product costs for low- and high-pressure Priority Products have been provided in Section 5.4.1. It should be noted that the material costs for low-pressure Priority Products were obtained from the websites of two large home improvement stores on October 5, 2020 (Home Depot, 2020; Lowe's, 2020), and these may change in the future. Labor costs are not provided, because low-pressure SPF products can be used by DIY applicators and labor costs for professional installers are not publicly available. Costs for high-pressure Priority Products were obtained from a 2010 United State Department of Energy (US DOE) publication (US DOE, 2010), which provided an approximate general cost for spray foam insulation that includes both materials and labor, with the caveat that insulation costs can vary greatly on the retail level.

External Cost. In order to quantify the potential public health costs of the Priority Products and possible alternatives, we looked for data on the number of cases of occupational asthma attributable to SPF use. This number could then be multiplied by the cost of treating an individual case of occupational asthma attributable to SPF use to obtain an estimate of overall health cost. As discussed in Section 5.4.2, we were unable to find such information; while data on the number of occupational asthma cases in California in general are available, there were no available data that would allow us to infer what percentage of those total cases are attributable to SPF use. For example, the most recent survey from California did not record any occupational asthma cases associated with the use of pMDI or SPF. Information was also not available for the lower-exposure approaches (whose introduction post-dates the available relevant studies) or the non-MDI-based alternative formulations (which are not currently in use). We did locate some estimates of the number of SPF workers on the national level, and in a Washington State study, we found data indicating one likely case of occupational asthma in a SPF applicator over a 11-year surveillance period (again, similar surveys in California identified no cases of occupational asthma attributable to SPF installation). While it could be possible to guess at the number of SPF workers in Washington State over this timeframe and divide the one case by that number to arrive at a prevalence estimate, this estimate would be highly uncertain. We would need data on both the number of workers in the industry in a given year and also the entry and exit rate of workers from the field to estimate the total number of unique workers who were covered by the 11-year surveillance period. It was not clear that such information could be reliably obtained. Moreover, we would be extrapolating from a single case, which seems like an unreliable approach. For instance, is the true prevalence one case in 20 years and the timing was such that the one case was observed because of the timing of the study or is the true prevalence one case in 5 years and the study just missed several cases? In addition, extrapolating a case number estimate from data in Washington State to a case number estimate for California might be inaccurate if there are different worker education programs or different characteristics of the working population between the two states (*e.g.*, differences in average job tenure). Overall, we considered the data too limited to make meaningful estimates of health costs for treating SPF-associated occupational asthma, let alone breaking out those costs specifically attributable to public health agencies, as required by the SCP regulations. As noted above, no data are available for the possible alternatives, so even if we were able to derive an estimate of public health costs for the Priority Products, there would be no comparison that could be drawn to support decision making.

In terms of environmental costs, we conducted Internet searches to try and find information related to the costs of managing waste related to the Priority Product or for remediating spills associated with the Priority Products. No information was identified that would be useful for cost estimation. Generally, we believe that this provision in the SCP regulations is not really meant to address a product like SPF that is applied and then becomes inert for its use and end-of-life phases. One can imagine other situations, *e.g.* agricultural chemicals, consumer products that produce residues when used, *etc*. where the Priority Product will be found in the environment and could have environmental impacts. In such cases, data on environmental costs could well be available or inferred. However, such is not the case with SPF. Moreover, as noted for the public health costs, data on the possible alternatives are also not available so no comparison can be drawn to support decision making.

Internal Cost. The REs cannot completely predict the cost to retool manufacturer facilities in order to meet the requirements of any potential new alternative's manufacturing process. Retooling manufacturing facilities may require expanding current manufacturing capacity or the development of new factories. Land prices and construction prices vary across the country. Any of the non-MDI-based alternative formulations would introduce a new chemistry into the SPF market. The REs cannot predict if any of the non-MDI-based alternative formulations will require new manufacturing equipment. Pricing for raw materials for new alternatives is also uncertain. These raw materials are likely not commodity products. There may also be additional cost for toxicity testing for new formulations. There will also be licensing fees associated with the intellectual property rights of the patent holders. The REs do not have exact figures for the size of the California SPF market, so used "Insulation Usage in New Homes and Residential Remodeling, 2020," a report published by Home Innovation Research Labs (2002) to estimate that SPF represents 6.1% of California insulation market. This number does not account for commercial construction. Finally, the REs do not have cost information on the non-MDI-based alternative formulations. Based on their expertise, the REs anticipate that these products could cost manufacturers 2 to 4 times what the Priority Products cost them to manufacturer.

9 References

American Chemistry Council (ACC). 2011. "New, Free Online Training Program for Spray Foam Application Helps Builders, Contractors Use In-Demand Product Safely and Effectively." Center for the Polyurethanes Industry (CPI), January 25. Accessed at https://www.americanchemistry.com/New-Free-Online-Training-Program-for-Spray-Foam-Application-Helps-Builders-Contractors-Use-In-Demand-Product-Safely-and-Effectively.

American Chemistry Council (ACC). 2012. "Guidance for Working with MDI and Polymeric MDI: Things You Should Know." Center for the Polyurethanes Industry. ISSUE AX-205. 7p., September. Accessed at https://polyurethane.americanchemistry.com/Resources-and-Document-Library/11364.pdf.

American Chemistry Council (ACC). 2014. "Polyurethanes and Thermal Degradation Guidance." AX 396. 2p., March. Accessed at https://polyurethane.americanchemistry.com/Resources-and-Document-Library/6936.pdf.

American Chemistry Council (ACC). 2016a. "Ventilation Considerations for Spray Polyurethane Foam: Guidance on Ventilation During Installation of Interior Applications of High-Pressure Spray Polyurethane Foam." Center for the Polyurethanes Industry; Spray Foam Coalition (SFC). 18p.

American Chemistry Council (ACC). 2016b. "Health and Safety Product Stewardship Workbook for High Pressure Application of Spray Polyurethane Foam (SPF)." 44p., June.

American Chemistry Council (ACC). 2018. "Guidelines for Management and Disposal of Hazardous Waste from Polyurethane Processing." Issue AX151. 12p., February. Accessed at https://polyurethane.americanchemistry.com/Resources-and-Document-Library/10311.pdf.

American Chemistry Council (ACC). 2019a. "Disposal of SPF chemicals." Center for the Polyurethanes Industry. Accessed at https://www.spraypolyurethane.org/dfisposal-spf-chemicals.

American Chemistry Council (ACC). 2019b. "Diisocyanates explained." Accessed at https://dii.americanchemistry.com/Diisocyanates-Explained.

American Chemistry Council (ACC). 2020. "Spill response [related to Spray Polyurethane Foam (SPF)]." Accessed at https://www.spraypolyurethane.org/spill-response.

American Chemistry Council (ACC); Spray Foam Coalition (SFC). 2012. "The Performance Value of Spray Polyurethane Foam." ACC Center for the Polyurethanes Industry. 2p.

American Conference of Governmental Industrial Hygienists (ACGIH). 2019. "2019 Guide to Occupational Exposure Values." American Conference of Governmental Industrial Hygienists (ACGIH). ACGIH Publication #0397. 259p.

Australia Dept. of Health. 2015. "Inventory Multi-Tiered Assessment and Prioritisation (IMAP): Human Health Tier II Assessment for Bisphenol A-based Epoxy Resins (CAS Nos. 1675-54-3; 25068-38-6)." National Industrial Chemicals Notification and Assessment Scheme (NICNAS), April 24.

Australia Dept. of Health. 2017. "Inventory Multi-Tiered Assessment and Prioritisation (IMAP): Human Health Tier II Assessment for 2-Propenoic Acid, 2-Ethyl-2-[[(1-Oxo-2-Propenyl)Oxy]Methyl]-1,3-Propanediyl Ester (CAS No. 15625-89-5)." National Industrial Chemicals Notification and Assessment Scheme (NICNAS), March 10.

Avar, G; Meier-Westhues, U; Casselmann, H; Achten, D. 2012. "Polymers for a sustainable environment and green energy." Accessed at https://www.sciencedirect.com/topics/materials-science/polyol.

Bailey, RE; Gard, A; den Haan, KH; Heimbach, F; Pemberton, D; Tadokoro, H; Takatsuki, M; Yakabe, Y. 2003. "The environment." In *MDI and TDI: Safety, Health and the Environment: A Source Book and Practical Guide*. (Eds.: Allport, DC; Gilbert, DS; Outterside, SM), John Wiley & Sons, Ltd., Chichester, England. p229-276. doi: 10.1002/0470865687.ch4. Accessed at https://www.diisocyanates.org/sites/dii/files/visual_select_file/4-the_environment.pdf.

Bratfisch, C; Gamez, J; Pirkl, HG. 2020. "Simulation of 4,4'-MDI Water Reaction (Draft)." Report to International Isocyanate Institute, Inc. III Project No. 707.

California Air Resources Board (CARB). 2009. "Definitions of VOC and ROG (Revised)." 6p., January. Accessed at https://ww3.arb.ca.gov/ei/speciate/voc_rog_dfn_1_09.pdf.

California Air Resources Board (CARB). 2018a. "Hydrofluorocarbon (HFC) prohibitions in California." November 29. Accessed at https://ww2.arb.ca.gov/resources/fact-sheets/hydrofluorocarbon-hfc-prohibitions-california.

California Air Resources Board (CARB). 2018b. "Requirements applicable to Table 1 of Section 95374(a)." 17 CCR 95375, December 27.

California Air Resources Board (CARB). 2020. "CARB identified toxic air contaminants." Accessed at https://ww2.arb.ca.gov/resources/documents/carb-identified-toxic-air-contaminants.

California Building Standards Commission. 2019a. "California Building Code: Plastic." 24 Pt. 2 CCR 26. p403-418. Accessed at https://codes.iccsafe.org/content/chapter/15480.

California Building Standards Commission. 2019b. "California Residential Code: Building Planning." 24 Pt. 2.5 CCR 3. p45-138. Accessed at https://codes.iccsafe.org/content/chapter/15524.

California Dept. of Consumer Affairs. 2019. "Home Furnishings and Thermal Insulation Act and Rules and Regulations (Including additional references to the Business and Professions Code)." Bureau of Household Goods and Services. 3 BPC; 4 CCR. 73p., May. Accessed at https://bhgs.dca.ca.gov/laws/hfti_regs.pdf.

California Dept. of Public Health (CalDPH). 2013. "Asthma in California: A Surveillance Report." Environmental Health Investigations Branch. 194p., May.

California Dept. of Toxic Substances Control (CalDTSC). 2012a. "Definitions." 22 CCR 69401.2, January 29. Accessed at https://govt.westlaw.com/calregs/Document/I6EDFEDA032A411E186A4EF11E7983D17?%20viewType=FullText&originationContext=documenttoc&transitionType=CategoryPageItem&contextData=(sc.Default).

California Dept. of Toxic Substances Control (CalDTSC). 2012b. "Environmental persistence." 22 CCR 69405.3, January 29. Accessed at https://govt.westlaw.com/calregs/Document/I79D58FD032A411E186A4EF11E7983D17?viewType=FullText&originationContext=documenttoc&transitionType=CategoryPageItem&contextData=(sc.Default).

California Dept. of Toxic Substances Control (CalDTSC). 2013. "Safer Consumer Products." 22 CCR 55. 72p. Accessed at https://dtsc.ca.gov/wp-content/uploads/sites/31/2018/07/SCP-Final-Regs-Text-10-01-2013.pdf.

California Dept. of Toxic Substances Control (CalDTSC). 2014. "Revised Priority Product Profile: Spray Polyurethane Foam Systems Containing Unreacted Methylene Diphenyl Diisocyanates." Safer Consumer Products Program. 30p., September.

California Dept. of Toxic Substances Control (CalDTSC). 2017a. "Alternatives Analysis Guide (Version 1.0)." Safer Products and Workplaces Program. 235p., June.

California Dept. of Toxic Substances Control (CalDTSC). 2017b. "Summary of Technical Information and Scientific Conclusions for Designating Spray Polyurethane Foam Systems with Unreacted Methylene Diphenyl Diisocyanates as a Priority Product (Revised)." Safer Consumer Products Program. 38p., February.

California Dept. of Toxic Substances Control (CalDTSC). 2018. "Spray polyurethane foam systems containing unreacted methylene diphenyl diisocyanates." 22 CCR 69511.2. 2p.

California Dept. of Toxic Substances Control (CalDTSC). 2019a. "Informational List of Candidate Chemicals and Chemical Groups." Safer Consumer Products Information Management System (CalSAFER). May 13. Accessed at https://calsafer.dtsc.ca.gov/cms/search/?type=Chemical.

California Dept. of Toxic Substances Control (CalDTSC). 2019b. "Safer Consumer Products (SCP): Regulatory Response." Accessed at https://dtsc.ca.gov/scp/regulatory-response.

California Division of Occupational Safety and Health (CalOSHA). 1993. "The Hazardous Substances List." 8 CCR 339, March 18. Accessed at https://www.dir.ca.gov/title8/339.html.

California Division of Occupational Safety and Health (CalOSHA). 2012. "Respiratory protection." 8 CCR 5144, January 18. Accessed at https://www.dir.ca.gov/Title8/5144.html.

California Energy Commission. 2018a. "2019 Building Energy Efficiency Standards for Residential and Nonresidential Buildings for the 2019 Building Energy Efficiency Standards (Title 24, Part 6, and Associated Administrative Regulations in Part 1)." 24 Pt. 1 CCR 6. 325p., December. Accessed at https://ww2.energy.ca.gov/2018publications/CEC-400-2018-020/CEC-400-2018-020-CMF.pdf.

California Energy Commission. 2018b. "Appendix JA4 - U-factor, C-factor, and Thermal Mass Data: Scope and purpose [24 Pt. 1 CCR 6]." In "2019 Building Energy Efficiency Standards for Residential and Nonresidential Buildings for the 2019 Building Energy Efficiency Standards (Title 24, Part 6, and Associated Administrative Regulations in Part 1)." December. Accessed at https://www.energycodeace.com/site/custom/public/reference-ace-2019/index.html#!Documents/ja41scopeandpurpose.htm.

California Office of Environmental Health Hazard Assessment (CalOEHHA). 2019a. "OEHHA Acute, 8-hour and Chronic Reference Exposure Level (REL) Summary." November 4. Accessed at https://oehha.ca.gov/air/general-info/oehha-acute-8-hour-and-chronic-reference-exposure-level-rel-summary.

California Office of Environmental Health Hazard Assessment (CalOEHHA). 2019b. "Public Health Goals (PHGs)." Accessed at https://oehha.ca.gov/water/public-health-goals-phgs.

California State Senate. 2018. "Senate Bill No. 1013: An act to add Section 39734 to the Health and Safety Code, and to add Division 45 (commencing with Section 76000) to the Public Resources Code, relating to greenhouse gases." SB 1013. 5p., September 13. Accessed at https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201720180SB1013.

California State Water Resources Control Board (CalSWRCB). 2020. "Drinking Water Notification Levels and Response Levels: An Overview." Division of Drinking Water. 16p., February 6. Accessed at https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/notificationlevels/notification_levels_response_levels_overview.pdf.

Carlisle Spray Foam Insulation. 2019. "Technical Data Sheet for FOAMSULATE™ 50 HY Open Cell Foam." 03.31.19 CSFI-10659. 2p.

Carter, WPL; Luo, D; Malkina, IL. 1999. "Investigation of the Atmospheric Ozone Formation Potential of Para Toluene Isocyanate and Methylene Diphenylene Diisocyanate (Final)." Report to Chemical Manufacturers Association, Diisocyanates Panel. 66p., March 8.

Clean Production Action. 2018. "GreenScreen Chemical Hazard Criteria." In "GreenScreen® for Safer Chemicals Hazard Assessment Guidance (Version 1.4)." 19p., January. Accessed at https://www.greenscreenchemicals.org/images/ee_images/uploads/resources/GreeScreen1.4-Annex1-1.18.pdf.

Clean Production Action. 2019. "GreenScreen® for Safer Chemicals." Accessed at https://www.cleanproduction.org/programs/greenscreen.

Cutcher, CE. 2016. "The Spray Foam Applicators Handbook." 40p. Accessed at https://paratussupply.com/wp-content/uploads/2017/01/All-about-Spray-Foam.pdf.

Danish Environmental Protection Agency (Danish EPA). 2015. "Alternatives to MDI in Consumer Products – with focus on coatings, adhesives and sealants." Environmental Project No. 1709. 80p. Accessed at https://www2.mst.dk/Udgiv/publications/2015/05/978-87-93352-22-3.pdf.

DAP Products Inc. 2019. "Technical Data Sheet for DAP® Touch 'n Seal ® 1.75 PCF ICC Spray Foam Kit - Cream." 4p., September 1. Accessed at https://www.dap.com/media/5176/tds-tns-175-pcf-icc-final.pdf.

Estonia, Health Board. 2018. "Substance Evaluation Conclusion as Required by REACH Article 48 and Evaluation Report for 4,4'-methylenediphenyl diisocyanate (CAS No. 101-68-8)." Submitted to European Chemicals Agency (ECHA). EC No 202-966-0. 28p., November 21.

European Chemicals Agency (ECHA). 2020. "Information on Chemical Substances; Registered substances; Reach dossiers." Accessed at https://echa.europa.eu/information-on-chemicals/registered-substances.

Federal Emergency Management Agency (FEMA). 2020. "Seismic building codes." October 9. Accessed at https://www.fema.gov/emergency-managers/risk-management/earthquake/seismic-building-codes.

Federal Trade Commission. 2020. "Regulations under Section 4 of the Fair Packaging and Labeling Act." 16 CFR 500. p540-553.

Figovsky, O; Potashnikova, R; Leykin, A; Shapovalov, L; Sivokon, S. 2015. "Method for Forming a Sprayable Nonisocyanate Polymer Foam Composition." US Patent 2015/0024138 A1. Nanotech Industries, Inc.; Polymate, Ltd. 11p., January 22. Accessed at https://patentimages.storage.googleapis.com/55/ab/0c/2c1120fe97b7a7/US20150024138A1.pdf.

Figovsky, O; Shapovalov, L; Leykin, A; Birukova, O; Potashnikova, R. 2013. "Recent advances in the development of non-isocyanate polyurethanes based on cyclic carbonates." *PU Mag.* 10(4):2-8.

Fiume, MM; Bergfeld, WF; Belsito, DV; Hill, RA; Klaassen, CD; Liebler, DC; Marks, JG Jr.; Shank, RC; Slaga, TJ; Snyder, PW; Gill, LJ; Heldreth, B. 2019. "Safety assessment of monosaccharides, disaccharides, and related ingredients as used in cosmetics." *Int. J. Toxicol.* 38(Suppl. 1):5S-38S. doi: 10.1177/1091581818814189.

Foley, P; Jin, X; Sonnenschein, MF; Wagner, NL; Yue, C. 2015. "Biodegradable Crosslinked Polymers." International Publication No. WO 2015/142564 A1. Dow Global Technologies LLC. 17p., September 24.

Gaco. c. 2020. "GacoProFill SYSTEM New Construction Installation Guide." MKWF5003 0916. 10p. Accessed at https://41z32e1503dj3gyqe3151089-wpengine.netdna-ssl.com/wp-content/uploads/Installation-Guide-GacoProFill-SYSTEM-New-Construction.pdf.

Gaco Western. 2016. "Product Data Sheet for GacoProFill® FR6500R Polyurethane Foam Insulation." 2p., September.

Gaco Western. 2017a. "Gaco Western shatters the spray foam isocyanate ceiling at SPFA this week." February 1. Accessed at https://gaco.com/gaco-western-shatters-spray-foam-isocyanate-ceiling-spfa-week.

Gaco Western. 2017b. "Safety Data Sheet for GacoProFill - POLYOL COMPONENT B spray foam insulation." 11p., September 20.

Gaco Western. 2020. "Gaco ProFill SYSTEM." Accessed at https://gaco.com/product-details/gacoprofill-system.

Global Syngas Technologies Council (GSTC). 2020. "Syngas production." Accessed at https://www.globalsyngas.org/syngas-production.

Hardcastle, JL. 2015. "Spray foam, made with recycled content, can earn builders 10 LEED points." October 14. Accessed at https://www.environmentalleader.com/2015/10/spray-foam-made-with-recycled-content-can-earn-builders-10-leed-points.

Healthy Building Network. 2020. "Pharos Service." Accessed at https://pharosproject.net.

Holladay, M. 2009. "Installing fiberglass right." July 10. Accessed at https://www.greenbuilding advisor.com/article/installing-fiberglass-right.

Home Depot. 2020. "Search results: Two component spray foam." October 5.

Home Innovation Research Labs. 2020. "Insulation Usage in New Homes and Residential Remodeling, 2020."

Hybrid Coating Technologies Inc. 2014. "Hybrid Enters into Rapidly Expanding Foam Insulation Market." 3p., May 9.

ICC Evaluation Service, LLC (ICC-ES). 2018. "Acceptance Criteria for Spray-Applied Foam Plastic Insulation." AC 377. 19p., April.

ICC Evaluation Service, LLC (ICC-ES). 2019. "ICC-ES Evaluation Report for ICP Adhesives & Sealants Handi Foam HVLP MD 2.0 Spray-Applied Insulation (Revised)." ESR-4287. 11p., January.

ICC Evaluation Service, LLC (ICC-ES). 2020a. "ICC-ES Evaluation Report for Touch N' Seal Class I FR Spray Foam System, Touch N' Foam Professional Class I FR Spray Foam System and Touch N' Seal HVAC 1.75 Spray Foam System (Revised)." ESR-3052. 7p., June. Accessed at https://icc-es.org/report-listing/esr-3052.

ICC Evaluation Service, LLC (ICC-ES). 2020b. "ICC-ES Evaluation Report for SWD Urethane SWD Quik-Shield® | 125 and SWD Quik-Shield® | 155 Coated Foam Roofing Systems (Revised)." ESR-2532. 5p., April.

ICP Building Solutions Group. 2019a. "Safety Data Sheet for HandiFoam® HVLP MD 2.0." 6p., January.

ICP Building Solutions Group. 2019b. "Safety Data Sheet for HandiFoam HVLP A-side." 7p., January.

ICP Building Solutions Group. 2019c. "Technical Data Sheet for HVLP MD 2.0 Drum System." TD003 ICP Building Solutions Group Rev 2/2019-2. 3p., February.

ICP Building Solutions Group. c. 2020. "ICP Group Continues Testing on Low Pressure Polyurethane Foam Emissions; HVLP (High Volume Low Pressure) Dispensing of SPF Drum Foam." 4p.

Im, J; Loffler, FE. 2016. "Fate of bisphenol A in terrestrial and aquatic environments." *Environ. Sci. Technol.* 50(16):8403-8416. doi: 10.1021/acs.est.6b00877.

Intergovernmental Panel on Climate Change (IPCC). 2013. "Climate Change 2013: The Physical Science Basis, Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change." (Eds.: Stocker, TF; Qin, D; Plattner, GK; Tignor, M; Allen, SK; Boschung, J; Nauels, A; Xia, Y; Bex, V; Midgley, PM). Cambridge University Press, Cambridge, UK. 1552p. Accessed at https://www.ipcc.ch/report/ar5/wg1.

International Agency for Research on Cancer (IARC). 1999. "4,4'-methylenediphenyl diisocyanate and polymeric 4,4'-methylenediphenyl diisocyanate." In *IARC Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Humans: Re-evaluation of Some Organic Chemicals, Hydrogen, and Hydrogen Peroxide: Volume 71, Part 3*. World Health Organization (WHO), Geneva. p1049-1058.

International Association of Plumbing and Mechanical Officials (IAPMO). 2018. "Uniform Evaluation Service (UES) Evaluation Report for Accella Polyurethane Systems, LLC Foamsulate 50-HY Spray-Applied Polyurethane Foam Plastic Insulation (Revised)." 540. 5p., August 29.

International Association of Plumbing and Mechanical Officials (IAPMO). 2019. "Uniform Evaluation Service (UES) Evaluation Report for Johns Manville JM Corbond III® Performance Insulation System (Revised)." 146. 9p., April 10.

International Code Council, Inc. (ICC). 2015. "Definitions: General." In *International Building Code*. 2 ICC 201, October. Accessed at https://codes.iccsafe.org/content/IBC2015/chapter-2-definitions.

International Isocyanate Institute. 1991. "Determination of Po/w for TDI and MDI and Preliminary Estimation of Water Solubilities for TDI and MDI (Final)." III Report No. 10914.

Intertek. 2018. "Code Compliance Research Report for Gaco FR6500R Spray-applied Polyurethane Insulation (Revised)." CCRR-1040. 7p., December 6.

Jin, X; Crain, SP; Schutter, D; Pa-Tankar, KK; Sonnenschein, MF. 2013. "Non-Isocyanate Rigid Polymer Foams by Carbon-Michael Addition, and Foaming Process." International Publication No. WO 2013/101682 A1. Dow Global Technologies LLC. 35p., July 4.

Johns Manville Inc. 2018. "Product Data Sheet for JM Corbond III® Closed-Cell Spray Polyurethane Foam." BID-110. 2p., September.

Labrecque, M; Malo, J; Alaoui, KM; Khalil Rabhi, K. 2011. "Medical surveillance programme for diisocyanate exposure." *Occup. Environ. Med.* 68(4):302-307. doi: 10.1136/oem.2010.055129.

Lefkowitz, D; Pechter, E; Fitzsimmons, K; Lumia, M; Stephens, AC; Davis, L; Flattery, J; Weinberg, J; Harrison, RJ; Reilly, MJ; Filios, MS; White, GE; Rosenman, KD. 2015. "Isocyanates and work-related asthma: Findings from California, Massachusetts, Michigan, and New Jersey, 1993-2008." *Am. J. Ind. Med.* 58(11):1138-1149.

Leigh, JP; Romano, PS; Schenker, MB; Kreiss, K. 2002. "Costs of occupational COPD and asthma." *Chest* 121(1):264-272. doi: 10.1378/chest.121.1.264.

LibreTexts Chemistry Library. 2015. "Hydrolysis of sucrose." March 19. Accessed at https://chem.libretexts.org/Courses/Purdue/Purdue%3A_Chem_26200%3A_Organic_Chemistry_II_(Wenthold)/Chapter_22._Carbohydrates/22.08%3A_Disaccharides/22.08.1%3A_Sucrose_vs_High-Fructose_Corn_Syrup/Sucrose.

Lee, BA. [California Dept. of Toxic Substances Control (CalDTSC)]. 2015. Letter to L. Salamone (American Chemistry Council (ACC), Center for the Polyurethanes Industry) [re: Proposal to adopt Spray Polyurethane Foam systems with MDI as one of the initial Priority Products under the Safer Consumer Product (SCP) program]. 3p., November 17.

Lowe's. 2020. "Search results: Two component spray foam." October 5.

Massaro, LM. [DuPont]. 2019. Email to S. Wieroniey (American Chemistry Council [ACC]) and T. Lewandowski and J. Zhang (Gradient) [re: Legal requirements for priority product]. July 30.

NanoSonic Inc. 2012. "New Foam Insulation Certified as 'Green' with Low Emissions." 3p., September 17. Accessed at https://www.nanosonic.com/wp-content/uploads/2015/12/PR-New-Foam-Insulation-Certified-as-Green-with-Low-Emissions.pdf.

NanoSonic Inc. 2013. "Final Report: VOC-free, Highly Flame Resistant HybridSil™ Insulation Coatings for Next Generation Thermal Insulation and Energy Efficiency." Report to US EPA, January 17. Accessed at https://cfpub.epa.gov/ncer_abstracts/index.cfm/fuseaction/display.abstractDetail/abstract/9660/report/F.

Nanotech Industries, Inc. 2020. "Green polyurethane." Accessed at https://nanotechindustriesinc.com/GPU.php.

National Institute for Occupational Safety and Health (NIOSH). 2020. "Asthma." Accessed at https://wwwn.cdc.gov/eWorld/Grouping/Asthma/97.

National Library of Medicine (NLM). 2003. "Hazardous Substances Data Bank (HSDB) record for phenol (CAS No. 108-95-2)." October 15. Accessed at https://toxnet.nlm.nih.gov.

National Library of Medicine (NLM). 2005-2013. "Hazardous Substances Data Bank (HSDB) records." Accessed at https://toxnet.nlm.nih.gov.

National Library of Medicine (NLM). 2015. "Hazardous Substances Data Bank (HSDB) record for formaldehyde (CAS No. 50-00-0)." October 19. Accessed at https://toxnet.nlm.nih.gov.

National Library of Medicine (NLM). 2018a. "Hazardous Substances Data Bank (HSDB) record for aniline (CAS No. 62-53-3)." November 28. Accessed at https://toxnet.nlm.nih.gov.

National Library of Medicine (NLM). 2018b. "Hazardous Substances Data Bank (HSDB) record for bisphenol A (CAS No. 80-05-7)." December 18. Accessed at https://toxnet.nlm.nih.gov.

National Library of Medicine (NLM). 2018c. "Hazardous Substances Data Bank (HSDB) record for acrylic acid (CAS No. 79-10-7)." July 26. Accessed at https://toxnet.nlm.nih.gov.

National Library of Medicine (NLM). 2020. "Hazardous Substances Data Bank (HSDB)." September 19. Accessed at https://www.nlm.nih.gov/toxnet/index.html.

Nelson, D. [Gaco Western]. 2015. "Spray Foam Installations with Reduced Occupational Exposure – Phase 1." American Chemistry Council (ACC). 9p.

Nurmagambetov, T; Kuwahara, R; Garbe, P. 2018. "The economic burden of asthma in the United States, 2008-2013." *Ann. Am. Thorac. Soc.* 15(3):348-356. doi: 10.1513/AnnalsATS.201703-259OC.

Occupational Safety and Health Administration (OSHA). 2012. "Hazard Communication (Final rule)." *Fed. Reg.* 77(58):17574-17896. 29 CFR Parts 1910, 1915, and 1926, March 26.

Occupational Safety and Health Administration (OSHA). 2017. "Occupational safety and health standards, Subpart Z - Toxic and hazardous substances: Hazard communication." 29 CFR 1910.1200. 129p.

Occupational Safety and Health Administration (OSHA). 2018. "Respiratory protection." 29 CFR 1910.134. 27p.

Olang, FN. 2012. "Hybrid Polyurethane Spray Foams Made with Urethane Prepolymers and Rheology Modifiers." US Patent 2012/0183694 A1. Owens Corning Intellectual Capital, LLC. 15p., July 19. Accessed at https://patentimages.storage.googleapis.com/e1/d0/23/1d14d5181d8641/US20120183694A1.pdf.

Olf, G. 2018. "Vapor Pressure of Various MDI-Based Substances." Report to International Isocyanate Institute, Inc. III Report No. 11711.

Organisation for Economic Co-operation and Development (OECD). 2002. "SIDS Initial Assessment Report for SIAM 14 on Sodium Hydroxide (CAS No. 1310-73-2)." UNEP Publications. 112p. Accessed on at https://hpvchemicals.oecd.org/UI/handler.axd?id=4d5cda68-5a7d-4ab6-85ec-20a0fd6592ca.

Organisation for Economic Co-operation and Development (OECD). 2020. "QSAR Toolbox (Version 4.4.1)." Accessed at https://qsartoolbox.org/download.

Peters, TJ. 2018. "Low Pressure Plural Component Spray System." US Patent 2018/0104709 A1. 10p., April 19.

Plehiers, P; West, RJ; Spence, MW; Chappelle, AH. [International Isocyanate Institute, Inc.]. 2019. "Reactivity of Aromatic Diisocyanate Substances with Water: A Review of Relevant Literature and III Project Learnings through September 2017." SO Report 2019/A.

Polyisocyanurate Insulation Manufacturers Association (PIMA). 2015. "Environmental Product Declaration: Polyiso Roof Insulation Boards." 12p., January 1.

Reeb-Whitaker, C; Anderson, NJ; Bonauto, DK. 2013. "Prevention guidance for isocyanate-induced asthma using occupational surveillance data." *J. Occup. Environ. Hyg.* 10.(11):597-608. doi: 10.1080/15459624.2013.818236.

Roberts, T. 2014. "What About Air Krete? A deeper look at the insulation alternative." April 2. Accessed at https://airkrete.com/pdf/What_About_AirKrete.pdf.

Schenke, B. [Premium Spray Products]. 2014. "Recoating and Renewing SPF Roofing Systems; Procedures, Regional Differences and Type of Coating Systems." Presented at the Sprayfoam Convention & Expo, Palm Springs, CA, January 26-29. 51p

Sendijarevic, V; Sendijarevic, A; Sendijarevic, I; Bailey, RE; Pemberton, D; Reimann, KA. 2004. "Hydrolytic stability of toluene diisocyanate and polymeric methylenediphenyl diisocyanate based polyureas under environmental conditions." *Environ. Sci. Technol.* 38(4):1066-1072. doi: 10.1021/es035072f.

Soudal Australia. 2020. "Soudafoam SMX." Accessed at http://soudal.com.au/expanding-foam/soudafoam-smx.

Soudal Inc. 2020. "Insulation [Product information]." Accessed at tps://soudalusa.com/professional/application/Insulation/6.

South Coast Air Quality Management District (SCAQMD). 2017. "Adhesive and Sealant Applications." Rule 1168. 25p., October 6. Accessed at http://www.aqmd.gov/docs/default-source/rule-book/reg-xi/rule-1168.pdf?sfvrsn=4.

Spray Foam Coalition (SFC). 2020a. "Types of spray foam and advantages." Accessed at https://www.whysprayfoam.org/spray-foam/types-spray-foam.

Spray Foam Coalition (SFC). 2020b. "Building strength." Accessed at https://www.whysprayfoam.org/builders/building-strength.

Spray Foam Systems (SFS). 2020. "Introducing a safer system process [Nitrosys HVLP]." *Spray Foam Mag.* Show Issue 2020:38-41.

Spray Polyurethane Foam Alliance (SPFA). 2020a. "Glossary of terms." Accessed at http://www.sprayfoam.org/technical/glossary.

Spray Polyurethane Foam Alliance (SPFA). 2020b. "SPFA Professional Certification Program (PCP)." Accessed at http://www.sprayfoam.org/certification.

Sustainable Solutions Corp. 2020. "Spray Polyurethane Foam Allegiance (SPFA)." 18p., June.

SWD Urethane. 2020. "Technical Data Sheet for QUIK-SHIELD® 125-3.0 3.0 lb. Roofing Spray Foam." SWD-TDS-PMG-330. 2p., August 15.

Syamlal, G; Bhattacharya, A; Dodd, KE. 2020. "Medical Expenditures Attributed to Asthma and Chronic Obstructive Pulmonary Disease Among Workers — United States, 2011–2015." *MMWR Morb. Mortal. Wkly. Rep*. 69(26):809-814.

thinkstep. 2018. "Life Cycle Assessment of Spray Polyurethane Foam Insulation (Version 1.1.)" Report to Spray Polyurethane Foam Alliance (SPFA). 54p., October 29.

Thomas, M; Wagner, NL; Stobby, WG; Praay, HN. 2018. "System for Dimensionally Stable Isocyanate-Free Polyurethane Foam." International Publication No. WO 2018/005142 A1. Dow Global Technologies LLC. 24p., January 4.

Trumbo, DL; Krogman, N; Nelson, DS. 2016. "Foam Compositions." US Patent 9,359,471 B2. Gaco Western, LLC. 24p., June 7. Accessed at https://patentimages.storage.googleapis.com/73/a0/94/0ce030e8ebcb50/US9359471.pdf.

Tury, B; Pemberton, D; Bailey, RE. 2003. "Fate and potential environmental effects of methylenediphenyl diisocyanate and toluene diisocyanate released into the atmosphere." *J. Air Waste Manag. Assoc*. 53(1):61-66. doi: 10.1080/10473289.2003.10466120.

UL LLC. 2020. "LOLI Desktop Database (Version ID 1044)." July 1.

Underwriters Laboratories, Inc. (UL). 2020. "UL GREENGUARD Certification Program." 3p. Accessed at https://www.ul.com/resources/ul-greenguard-certification-program.

United Nations (UN). 2019. "Globally Harmonized System of Classification and Labelling of Chemicals (GHS) (Eighth Revised Edition)." ST/SG/AC.10/30/Rev.8. 570p. Accessed at https://www.unece.org/fileadmin/DAM/trans/danger/publi/ghs/ghs_rev08/ST-SG-AC10-30-Rev8e.pdf.

US Consumer Product Safety Commission (US CPSC). 2017. "Subchapter C - Federal Hazardous Substances Act regulations: Hazardous substances and articles: Administrative and enforcement regulations." 16 CFR 1500. 113p.

US Consumer Product Safety Commission (US CPSC). 2020. "Federal Hazardous Substances Act (FHSA) Requirements." Accessed at https://www.cpsc.gov/Business--Manufacturing/Business-Education/Business-Guidance/FHSA-Requirements.

US Dept. of Energy (US DOE). 2010. "Guide to Home Insulation." DOE/EE-0340. 2p., October.

US Dept. of Energy (US DOE). 2020a. "Insulation." Accessed at https://www.energy.gov/energysaver/weatherize/insulation.

US Dept. of Energy (US DOE). 2020b. "Insulation materials." Accessed at https://www.energy.gov/energysaver/weatherize/insulation/insulation-materials.

US Dept. of Transportation (US DOT). 2019. "How to comply with Federal hazardous materials regulations." Federal Motor Carrier Safety Administration, Analysis Division (FMCSA). Accessed at https://www.fmcsa.dot.gov/regulations/hazardous-materials/how-comply-federal-hazardous-materials-regulations.

US EPA. 1998. "IRIS Chemical Assessment Summary for Methylene diphenyl diisocyanate (monomeric MDI) and polymeric MDI (PMDI) (CAS Nos. 101-68-8, 9016-87-9)." 23p., February 7. Accessed at https://www.epa.gov/iris.

US EPA. 2005. "Petition to remove 4,4'-methylene diphenyl diisocyanate from the list of hazardous air pollutants (Notice of receipt of a complete petition to delist 4,4'-methylene diphenyl diisocyanate from the list of hazardous air pollutants)." *Fed. Reg.* 70(101):30407-30409. 40 CFR 63. May 26.

US EPA. 2011. "Methyl Diphenyl Diisocyanate (MDI) and Related Compounds Action Plan [RIN 2070-ZA15]." 15p., April. Accessed at https://www.epa.gov/sites/production/files/2015-09/documents/mdi.pdf.

US EPA. 2013. "Interpretive Assistance Document for Assessment of Discrete Organic Chemicals: Sustainable Futures Summary Assessment." Office of Pollution Prevention & Toxics. 20p., June. Accessed at https://www.epa.gov/sites/production/files/2015-05/documents/05-iad_discretes_june2013.pdf.

US EPA. 2016. "Spray polyurethane foam product types." September 12.

US EPA. 2018a. "Requirements for Preparation, Adoption, and Submittal of Implementation Plans, Subpart F – Procedural Requirements: Definitions." 40 CFR 51.100. 7p.

US EPA. 2018b. "Ozone-depleting substances." July 31. Accessed at https://www.epa.gov/ozone-layer-protection/ozone-depleting-substances.

US EPA. 2019a. "Draft Risk Evaluation for 1,4-Dioxane (CAS No. 123-91-1)." Office of Chemical Safety and Pollution Prevention. EPA Document # EPA-740-R1-800-7. 407p., June.

US EPA. 2019b. "EPI Suite™ - Estimation Program Interface." Accessed at https://www.epa.gov/tsca-screening-tools/epi-suitetm-estimation-program-interface.

US EPA. 2019c. "CompTox Chemicals Dashboard." Accessed at https://comptox.epa.gov/dashboard.

Verschoor, L; Verschoor, AH. 2014. "Nonoccupational and occupational exposure to isocyanates." *Curr. Opin. Pulm. Med.* 20(2):199-204. doi: 10.1097/MCP.0000000000000029.

Verslycke, T; Reid, K; Bowers, T; Thakali, S; Lewis, A; Sanders, J; Tuck, D. 2014. "The Chemistry Scoring Index (CSI): A hazard-based scoring and ranking tool for chemicals and products used in the oil and gas industry." *Sustainability* 6:3993-4009. doi: 10.3390/su6073993.

Washington State Dept. of Labor & Industries. 2015. "Work-Related Asthma in Washington State, 2009-2013." Safety and Health Assessment and Research Prevention (SHARP) Program. Technical Report 75-12-2015. 27p., May. Accessed at https://lni.wa.gov/safety-health/safety-research/files/2015/75_12_2015Asthma_2015_V6.pdf.

Wishneski, TW; Ogonowski, J; Jean-Rejouis, M; Hunter, M. [BASF DE]. 2017. "Polyurethane Spraying System Used to Minimize Emissions of a Polyisocyanate." US Patent 9,592,596 B2. 25p., March 14.

Wishneski, TW; Szyndler, MW; Bower, DK; Hunter, MJ; Moore, CA. [BASF DE]. 2019. "Polyurethane Compositions with Low Exposure to Free Monomeric MDI Isocyanate Content During Spray Application." International Publication No. WO 2019/089237 A1. 76p., May 9.

Wood, R. [Air Products and Chemicals, Inc.]. 2014. "CPI Ventilation Research Project for Estimating Re-entry Times for Trade Workers Following Application of Three Generic Spray Polyurethane Foam Formulations." American Chemistry Council. 15p.

Wood, RD. 2017. "Center for the Polyurethanes Industry summary of unpublished industrial hygiene studies related to the evaluation of emissions of spray polyurethane foam insulation." *J. Occup. Environ. Hyg*. 14(9):681-693. doi: 10.1080/15459624.2017.1320562.

Yakabe, Y; Henderson, KM; Thompson, WC; Pemberton, D; Tury, B; Bailey, RE. 1999. "Fate of methylenediphenyl diisocyanate and toluene diisocyanate in the aquatic environment." *Environ. Sci. Technol.* 33(15):2579-2583. doi: 10.1021/es981350c.

Tables

Table 4.3 Manufacturing Information for Priority Products

Priority Product Group[1]	Chemical	Production Process	Precursor Fossil Fuel Based?	Other Notable Chemicals Involved in Production
All Groups	Unreacted MDI (CAS Nos. 101-68-8 and 26447-40-5) and pMDI (CAS No. 9016-87-9)	MDI is produced *via* the condensation of aniline and formaldehyde, yielding diphenylmethane diamine. This is subsequently reacted with phosgene to form a mixtures of MDI and pMDI. MDI itself is distilled from the pMDI/MDI reaction product.	Yes. Aniline is primarily produced from nitrobenzene and phenol, both of which are produced from fossil-fuel-derived hydrocarbons. Both formaldehyde and phosgene are primarily derived from the reaction of synthesis gas, which can be obtained from fossil fuels or biomass.	Aniline, Formaldehyde, Phosgene, Diphenylmethane Diamine
Group 1	Polymer in Polyester Polyol (No CAS No. identified)	Polyester polyols are manufactured by the reaction of chemicals such as butanediol or hexanediol with dicarboxylic acids such as adipic acid or terephthalic acid (Avar *et al.* , 2012). The polyols can also be created from recycling of PET.	Possibly. Alkyl diols are likely derived from fossil fuels, and the dicarboxylic acids may be derived from plant or animal matter (although terephthalic acid is produced from xylene, which is derived from fossil fuels). Alternatively, some manufacturers obtain polyols from recycled PET, often from recycled plastic bottles.	Alkyl Diols
	Diethylene Glycol in Polyester Polyol (CAS No. 111-46-6, 30%)	Diethylene glycol is produced as a byproduct of ethylene glycol production, which in turn is produced by he hydrolysis of ethylene oxide.	Yes. The original ethylene oxide starting material is produced from ethylene which can be derived from fossil fuels.	Ethylene Glycol
	Option A: Polyether Polyol (*e.g.* , oxirane, 2-methyl-, polymer with oxirane, ether with 1,2,3-propanetriol [3:1] [CAS No. 9082-00-])	Polyether polyols are manufactured by the reaction of cyclic ethers such as ethylene oxide and propylene oxide with chemicals such as fatty acids or fatty alcohols (Avar *et al.* , 2012).	Yes. Ethylene and propylene oxide are typically derived from ethylene and propylene obtained from fossil fuel sources. The other reactants may be derived from fossil fuels or non-fossil fuel sources.	Ethylene Oxide
	Option B: Polyether Polyol (*e.g.* , sucrose, propylene oxide [CAS No. 9049-71-2])	Formed *via* the reaction of sucrose and propylene oxide.	Not entirely. Sucrose is derived from biological sources (*e.g.* , sugar cane, sugar beets). Propylene oxide is derived from propylene, which in turn is typically obtained from fossil fuels.	Propylene Oxide
Group 2	**Option A:** Polyether Polyol (*e.g.* , oxirane, 2-methyl-, polymer with oxirane, ether with 1,2,3-propanetriol [3:1] [CAS No. 9082-00-2])	See above.	See above.	See above.
	Option B: Polyether Polyol (*e.g.* , sucrose, propylene oxide [CAS No. 9049-71-2])	See above.	See above.	See above.
Group 3	Polymer in Polyester Polyol (No CAS No. identified)	See above.	See above.	See above.
	Diethylene Glycol in Polyester Polyol (CAS No. 111-46-6, 30%)	See above.	See above.	See above.
	Aromatic Amino Polyether Polyol (*e.g.* , oxirane, 2-methyl-, polymer with oxirane, ether with 2,6-bis((bis(2-hydroxyethyl) amino)methyl)-4-branched nonylphenol [CAS No. 940912-28-7])	No data were found regarding the manufacture of this chemical.	Likely, although no specific data were identified.	

Notes:
MDI = Methylene Diphenyl Diisocyanate; PET = Polyethylene Terephthalate; pMDI = Polymeric Methylene Diphenyl Diisocyanate.
Based on information obtained from the Hazardous Substances Data Bank (HSDB) (NLM, 2020) unless otherwise indicated.
(1) No generic formula exists for Group 4 Priority Products.

Table 4.4 Manufacturing Information for Non-MDI-based Alternative Formulations

Non-MDI-based Alternative Formulation	Chemical	Production Process	Precursor Fossil Fuel Based?	Other Notable Chemicals Involved in Production
Firestone/Gaco Canary™ Example Formulation	Sucrose Acetoacetate (No CAS No. identified)	Produced by the esterification of sucrose with organic acids.	Sucrose is derived from bio-based sources. No data were found on the production of acetoacetic acid, but it is likely produced from acetic acid, which can be produced *via* the fermentation of sugars or the carbonylation of methanol.	Possibly Methanol
	Glycerine Acetoacetate (No CAS No. identified)	Produced by the esterification of glycerin with organic acids.	Glycerin is derived from bio-based sources. No data were found on the production of acetoacetic acid, but it is likely produced from acetic acid, which can be produced *via* the fermentation of sugars or the carbonylation of methanol.	Possibly Methanol
	Meta Xylene Diamine (MXDA) (CAS No. 1477-55-0)	Produced by hydrogenation of isophthalonitrile which is in turn derived from xylene.	Yes. Production based on xylene, which is likely derived from fossil fuel sources.	Xylene
	Dytek® A (2-Methyl-1,5-diaminopentane) (CAS No. 15520-10-2)	Obtained *via* the reaction of epichlorohydrin and bisphenol A. Bisphenol A is manufactured from phenol and acetone, with phenol being produced from several different aromatic hydrocarbons. Epichlorohydrin is produced by the chlorination of propylene.	Yes. It appears that some of the base ingredients for this chemical are hydrocarbons (*e.g.* , aromatics and propylene).	Bisphenol A, Epichlorohydrin
Hybrid Coatings Technologies/Nanotech Industries Green Polyurethane™ Example Formulation	DER 331, Bisphenol-A Epoxy Resin (CAS No. 25085-99-8)	No data obtained but likely produced *via* the reaction of epichlorohydrin and bisphenol A. Bisphenol A is manufactured from phenol and acetone, with phenol being produced from several different aromatic hydrocarbons. Epichlorohydrin is produced by the chlorination of propylene.	Yes. It appears that some of the base ingredients for this chemical are hydrocarbons (*e.g.* , aromatics and propylene).	Bisphenol A, Epichlorohydrin
	Ancamine 2678 (No CAS No. identified)	The product is described as an alkyl amine. Alkyl amines are generally formed by reaction of halocarbons with ammonia. Given that the exact chemical nature of ancamine 2678 is not disclosed no further evaluation is possible.	Likely. The base hydrocarbons are likely derived from fossil fuel sources.	Halocarbons (exact chemicals unspecified)
Owens Corning Example Formulation	DER 331, Bisphenol-A Epoxy Resin (CAS No. 25085-99-8)	See above.	See above.	See above.
	Epon™ 8111, Multifunctional Epoxy Resin (CAS No. 25068-38-6)	CAS No. 25068-38-6 (one component of the material) is described as chloromethyl)oxirane, 4,4'-(1-methylethylidene)bisphenol copolymer. Production therefore likely involves bisphenol A. No further information is available.	Likely.	Bisphenol A
	Epon™ 8111, Multifunctional Epoxy Resin (CAS No. 15625-89-5)	CAS No. 15625-89-5 (one component of the material) is described as trimethylolpropane triacrylate. Production of this compound is reported to be by esterification of trimethylolpropane, which is itself formed by the condensation of butyraldehyde and formaldehyde.	Yes. It appears that some of the base ingredients for this chemical are hydrocarbons (*e.g.* , propylene).	Formaldehyde
	Cycloate A (CAS No. 1134-23-2)/ Ancamine 2678 (No CAS No. identified)	No data were located on the manufacture of cycloate A. For ancamine 2678, see above.	Unclear, due to the lack of specific chemical identity.	Unknown
	Epikure™ 3271 (CAS No. 111-40-0)	The CAS No. given is for diethylenetriamine. Production of this chemical involves the reaction of ethylene dichloride and ammonia, the former of which is produced from ethylene.	Likely. The base hydrocarbons are likely derived from fossil fuel sources.	Ethylene Dichloride
	Epikure™ 3271 (CAS No. 80-05-7)	The CAS No. given is for bisphenol A. Bisphenol A is manufactured from phenol and acetone, with phenol being produced from several different aromatic hydrocarbons.	Yes. At least one of the base ingredients (phenol) is likely derived from fossil fuel sources.	Bisphenol A
DuPont Patent No. WO 2013/101682 A1 Example Formulation	Tetrafunctional Acrylate (CAS No. 94108-97-1)	The CAS No. given is for ditrimethylolpropane tetraacrylate. Presumably involves the reaction of trimethylolpropane, which is formed by the condensation of butyraldehyde and formaldehyde. Also likely involves the reaction of acrylic acid.	Yes. It appears that some of the base ingredients for this chemical are hydrocarbons (*e.g.* , propylene).	Formaldehyde
	Difunctional Acrylate A (CAS No. 55818-57-0)	No data were found for this chemical.	Unclear, due to the lack of specific chemical identity.	Unknown
	Trimethylolpropane tris(Acetoacetonate) (CAS No. 22208-25-9)	No data were found for this chemical. Presumably involves the reaction of trimethylolpropane, which is formed by the condensation of butyraldehyde and formaldehyde.	Likely.	Formaldehyde

Non-MDI-based Alternative Formulation	Chemical	Production Process	Precursor Fossil Fuel Based?	Other Notable Chemicals Involved in Production
Dow Patent No. WO 2015/142564 A1 Example Formulation	Polycarbamate (No CAS No. identified, reaction product)	No data were found for this chemical.	Unclear, due to the lack of specific chemical identity.	Unknown
	1,3- and 1,4-Cyclohexane Dicarboxaldehyde (CHDA) (EC No. 482-020-3, No CAS No.)	No data were found for this chemical.	Likely. The chemical presumably is derived from cyclohexane or phthalic acid which are obtained from fossil fuel sources.	Unknown
DuPont Patent No. WO 2018/005142 A1 Example Formulation	Polycarbamate 2 (No CAS No. identified)	No data were found for this chemical.	Unclear due to the lack of specific chemical identity.	Unknown
	1,3- and 1,4-Cyclohexane Dicarboxaldehyde (CHDA) (EC No. 482-020-3, No CAS No.)	No data were found for this chemical.	Likely. The chemical is presumably derived from cyclohexane or phthalic acid, which are obtained from fossil fuel sources.	Unknown

Notes:
MDI = Methylene Diphenyl Diisocyanate.
Based on information obtained from the Hazardous Substances Data Bank (HSDB) (NLM, 2020) unless otherwise indicated.

Table 4.5 Manufacturing Information for Lower-Exposure Approaches

Lower-Exposure Approaches	Chemical	Production Process	Precursor Fossil Fuel Based?	Other Notable Chemicals Involved in Production
Firestone/Gaco Profill System™	Unreacted MDI (CAS Nos. 101-68-8 and 26447-40-5) and pMDI (CAS No. 9016-87-9)	See above.	See above.	See above.
	beta-D-Fructofuranosyl alpha-D-glucopyranoside/Sucrose (CAS No. 57-50-1)	See above.	See above.	See above.
High-Volume Low-Pressure (HVLP) Systems (*e.g.* , Nitrosys/ICP HandiFoam HVLP MD 2.0)	Unreacted MDI (CAS Nos. 101-68-8 and 26447-40-5) and pMDI (CAS No. 9016-87-9)	See above.	See above.	See above.
	Polymer in Polyester Polyol (No CAS No. identified)	Polyester polyols are manufactured by the reaction of chemicals such as butanediol or hexanediol with dicarboxylic acids such as adipic acid or terephthalic acid (Avar *et al.* , 2012).	Likely. Alkyl diols are likely derived from fossil fuels, and the dicarboxylic acids may be derived from plant or animal matter (although terephthalic acid is produced from xylene, which is derived from fossil fuels). Some manufacturers are also able to produce the product from recycled PET.	Alkyl Diols
	Diethylene Glycol in Polyester Polyol (CAS No. 111-46-6)	See above.	See above.	See above.
	Aromatic Amino Polyether Polyol (*e.g.* , oxirane, 2-methyl-, polymer with oxirane, ether with 2,6-bis((bis(2-hydroxyethyl) amino)methyl)-4-branched nonylphenol [CAS No. 940912-28-7])	No data were found regarding the manufacture of this chemical.	Likely, although no specific data were identified.	
BASF Patent No. 9592516 B2 Example Formulation	Unreacted MDI (CAS Nos. 101-68-8 and 26447-40-5) and pMDI (CAS No. 9016-87-9)	MDI is produced *via* the condensation of aniline and formaldehyde, yielding diphenylmethane diamine. This is subsequently reacted with phosgene to form a mixtures of MDI and pMDI. MDI itself is distilled from the pMDI/MDI reaction product.	Yes. Aniline is primarily produced from nitrobenzene and phenol, both of which are produced from fossil-fuel-derived hydrocarbons. Both formaldehyde and phosgene are primarily derived from the reaction of synthesis gas, which can be obtained from fossil fuels or	Aniline, Formaldehyde, Phosgene, Diphenylmethane Diamine
	Diethylene Glycol (CAS No. 111-46-6)	Diethylene glycol is produced as a byproduct of ethylene glycol production, which in turn is produced by the hydrolysis of ethylene oxide.	Yes. The original ethylene oxide starting material is produced from ethylene, which can be derived from fossil fuels.	Ethylene Glycol
	Polyether Polyol (*e.g.* , oxirane, 2-methyl-, polymer with oxirane, ether with 1,2,3-propanetriol [3:1] [CAS No. 9082-00-2])	Polyether polyols are manufactured by the reaction of cyclic ethers such as ethylene oxide and propylene oxide with di- or multifunctional starter molecule such as fatty acids or fatty alcohols (Avar *et al.* , 2012).	Yes. Ethylene and propylene oxide are typically derived from ethylene and propylene obtained from fossil fuel sources. The other reactants may be derived from fossil fuels or non-fossil fuel sources.	Ethylene Oxide, Propylene Oxide
	Polyether Polyol (*e.g.* , sucrose, propylene oxide [CAS No. 9049-71-2])	Formed *via* the reaction of sucrose and propylene oxide.	Sucrose is derived from biological sources (*e.g.* , sugar cane, sugar beets). Propylene oxide is derived from propylene, which is typically obtained from fossil fuels.	Propylene Oxide
BASF Patent No. WO 2019/089237 A1 Example Formulation	Unreacted MDI (CAS Nos. 101-68-8 and 26447-40-5) and pMDI (CAS No. 9016-87-9)	See above.	See above.	See above.
	Aromatic Polyester (*e.g.* , Terol 258) (No CAS No. identified)	Polyester polyols. See above.	See above.	See above.
	GSP-280 Polyol (CAS No. 26301-10-0)	Sucrose-based polyol. See above.	See above.	See above.
	GSP-280 Polyol (CAS No. 9082-00-2)	Glycerin-based polyol. Like sucrose-based polyols, the glycerin moiety is likely derived from bio-based sources, whereas the propylene oxide reactant is likely derived from fossil-fuel-based sources.	Partially. The glycerin portion of the chemical is likely bio-based, and the propylene oxide used in production is likely derived from fossil fuels.	Propylene Oxide

Notes:

MDI = Methylene Diphenyl Diisocyanate; PET = Polyethylene Terephthalate; pMDI = Polymeric Methylene Diphenyl Diisocyanate.

Based on information obtained from the Hazardous Substances Data Bank (HSDB) (NLM, 2020) unless otherwise indicated.

Table 5.2 Functional Ingredient-specific Human Health Hazards (Group A Endpoints)[1]

Priority Product and Potential Alternatives	Functional Ingredients	Percentage of Product (A- and B-Sides Combined)	Score	Group A Endpoints											
				Acute Mammalian Toxicity	Carcinogenicity	Eye Irritation/ Corrosion	Skin Irritation/ Corrosion (Dermatotoxicity)	Germ Cell Mutagenicity	Target Organ Toxicity – Single Exposure	Target Organ Toxicity – Repeated Exposure	Reproductive/ Developmental Toxicity	Sensitizer – Respiration	Sensitizer – Skin	Endocrine Disruptor (EU Priority List)	California Proposition 65
Priority Product[2]															
MDI/pMDI in all Priority Products	Unreacted MDI (CAS Nos. 101-68-8 and 26447-40-5)/pMDI (CAS No. 9016-87-9)	46.25-50		Oral: Not Classified; Dermal: Not Classified; Inhalation: Cat. 4	Cat. 2[3]	Cat. 2	Cat. 2	Not Classified	Cat. 3 (respiratory irritation)	Cat. 2 (inhalation)	Not Classified	Cat. 1	Cat. 1B	Not Listed	Not Listed
			245	10	75	10	10	0	15	25	0	50	50	0	N/A
Generic Formula for Group 1 (Low Pressure, Various Densities)	Polymer in Polyester Polyol (TSCA-exempted polymer, CAS No. may not have been assigned, 70%)	11.5		DG for all endpoints. Unable to assess due to generic name and lack of CAS No.											
			120	5	25	5	5	25	5	5	25	5	5	10	N/A
	Diethylene Glycol in Polyester Polyol (CAS No. 111-46-6, 30%)			Oral: Cat. 4; Dermal: Not Classified; Inhalation: Not Classified	Not Classified	Not Classified	Not Classified	Not Classified	Not Classified	Not Classified	Not Classified	DG	Not Classified	Not Listed	Not Listed
			10.00	5	0	0	0	0	0	0	0	5	0	0	N/A
	Option A: Polyether Polyol (*e.g.* , oxirane, 2-methyl-, polymer with oxirane, ether with 1,2,3-propanetriol [3:1] [CAS No. 9082-00-2])	11.5		Oral: Cat. 4; Dermal: DG; Inhalation: DG	DG	Cat. 2	DG	DG	DG	DG	DG	DG	DG	Not Listed	Not Listed
			135	5	25	5	10	25	10	10	25	10	10	0	N/A
	Option B: Polyether Polyol (*e.g.* , sucrose, propylene oxide [CAS No. 9049-71-2])	11.5		Oral: Not Classified; Dermal: Not Classified; Inhalation: DG	Not Classified	Not Classified	Not Classified	Not Classified	Not Classified	Not Classified	Not Classified	DG	Not Classified	Not Listed	Not Listed
			10	0	0	0	0	0	0	0	0	10	0	0	N/A
	Total Human Health Score		**385-510**												
Generic Formula for Group 2 (High Pressure, Open Cell, 0.5 lb/ft^3)	**Option A:** Polyether Polyol (*e.g.* , oxirane, 2-methyl-, polymer with oxirane, ether with 1,2,3-propanetriol [3:1] [CAS No. 9082-00-2])	17		Oral: Cat. 4; Dermal: DG; Inhalation: DG	DG	Cat. 2	DG	DG	DG	DG	DG	DG	DG	Not Listed	Not Listed
			135	5	25	5	10	25	10	10	25	10	10	0	N/A
	Option B: Polyether Polyol (*e.g.* , sucrose, propylene oxide [CAS No. 9049-71-2])	17		Oral: Not Classified; Dermal: Not Classified; Inhalation: DG	Not Classified	Not Classified	Not Classified	Not Classified	Not Classified	Not Classified	Not Classified	DG	Not Classified	Not Listed	Not Listed
			10	0	0	0	0	0	0	0	0	10	0	0	N/A
	Total Human Health Score		**255-380**												
Generic Formula for Group 3 (High Pressure, Medium Density, Closed Cell, 2 lbs/ft^3)	Polymer in Polyester Polyol (TSCA-exempted polymer, CAS No. may not have been assigned, 70%)	18.2		DG for all endpoints. Unable to assess due to generic name and lack of CAS No.											
			155.00	10	25	10	10	25	10	10	25	10	10	10	N/A
	Diethylene Glycol in Polyester Polyol (CAS No. 111-46-6, 30%)			Oral: Cat. 4; Dermal: Not Classified; Inhalation: Not Classified	Not Classified	Not Classified	Not Classified	Not Classified	Not Classified	Not Classified	Not Classified	DG	Not Classified	Not Listed	Not Listed
			10.00	5	0	0	0	0	0	0	0	5	0	0	N/A
	Aromatic Amino Polyether Polyol (*e.g.* , oxirane, 2-methyl-, polymer with oxirane, ether with 2,6-bis((bis(2-hydroxyethyl)amino)methyl)-4-branched nonylphenol [CAS No. 940912-28-7])	16.81		DG	DG	DG	DG	DG	DG	DG	DG	DG	DG	Not Listed	Not Listed
			145.00	10	25	10	10	25	10	10	25	10	10	0	N/A
	Total Human Health Score		**555.00**												
Non-MDI-based Alternative Formulations															
Firestone/Gaco Canary™ Example Formulation	Sucrose Acetoacetate (No CAS No. identified)	26.09		DG for all endpoints. Unable to assess due to generic name and lack of CAS No.											
			155.00	10	25	10	10	25	10	10	25	10	10	10	N/A
	Glycerine Acetoacetate (No CAS No. identified)	26.09		DG for all endpoints. Unable to assess due to generic name and lack of CAS No.											
			155.00	10	25	10	10	25	10	10	25	10	10	10	N/A
	Meta Xylene Diamine (MXDA) (CAS No. 1477-55-0)	15.48		Oral: Cat 4; Dermal: Not Classified; Inhalation: Cat. 4	Not Classified	Cat. 1	Cat. 1B	Not Classified	DG	Not Classified	Not Classified	DG	Cat. 1B	Not Listed	Not Listed
			70.00	5	0	10	10	0	10	0	0	10	25	0	N/A
	Dytek® A (2-Methyl-1,5-diaminopentane) (CAS No. 15520-10-2)	10.26		Oral: Cat. 4; Dermal: Cat. 4; Inhalation: Cat. 4	DG	Cat. 1	Cat. 1A	Not Classified	Cat. 3 (respiratory irritation)	Not Classified	Not Classified	DG	Not Classified	Not Listed	Not Listed
			65.00	5	25	10	10	0	5	0	0	10	0	0	N/A
	Total Human Health Score		**445.00**												
Hybrid Coatings Technologies/Nanotech Industries Green Polyurethane™ Example Formulation	DER 331, Bisphenol-A Epoxy Resin (CAS No. 25085-99-8)	81.80		Oral: DG; Dermal: Cat. 4; Inhalation: DG	Cat. 2 (modeled)	DG	Cat. 2 (modeled)	Cat. 2 (modeled)	DG	DG	DG	DG	Cat. 1 (modeled)	Present	Not Listed
			420.00	10	75	25	10	25	50	50	50	50	50	25	N/A
	Ancamine 2678 (No CAS No. identified)	14.30		DG for all endpoints. Unable to assess due to generic name and lack of CAS No.											
			155.00	10	25	10	10	25	10	10	25	10	10	10	N/A
	Total Human Health Score		**575.00**												

Priority Product and Potential Alternatives	Functional Ingredients	Percentage of Product (A- and B-Sides Combined)	Score	Group A Endpoints											
				Acute Mammalian Toxicity	Carcinogenicity	Eye Irritation/ Corrosion	Skin Irritation/ Corrosion (Dermatotoxicity)	Germ Cell Mutagenicity	Target Organ Toxicity – Single Exposure	Target Organ Toxicity – Repeated Exposure	Reproductive/ Developmental Toxicity	Sensitizer – Respiration	Sensitizer – Skin	Endocrine Disruptor (EU Priority List)	California Proposition 65
Owens Corning Example Formulation	DER 331, Bisphenol-A Epoxy Resin (CAS No. 25085-99-8)	45.73		Oral: DG; Dermal: Cat. 4; Inhalation: DG	Cat. 2 (modeled)	DG	Cat. 2 (modeled)	Cat. 2 (modeled)	DG	DG	DG	DG	Cat. 1 (modeled)	Present	Not Listed
			345.00	10	75	25	10	25	25	25	50	25	50	25	N/A
	Epon™ 8111, Multifunctional Epoxy Resin (CAS No. 25068-38-6, ~50%)	16.34		Oral/Dermal/Inhalation: Not Classified	DG	Cat. 2	Cat. 2	DG	DG	DG	Not Classified	Not Classified	Cat. 1	Not Listed	Not Listed
			95.00	0	25	5	5	25	5	5	0	0	25	0	N/A
	Epon™ 8111, Multifunctional Epoxy Resin (CAS No. 15625-89-5, ~50%)			Oral/Dermal/Inhalation: Not classified	Not Classified	Cat. 2	Cat. 2	Not Classified	Not Classified	Not Classified	Not Classified	Cat. 1A (Pharos)	Cat. 1	Not Listed	Not Listed
			60.00	0	0	5	5	0	0	0	0	25	25	0	N/A
	Cycloate A (CAS No. 1134-23-2)/ Ancamine 2678 (no CAS No. identified, thus not evaluated)	17.49		Oral: Not Classified; Dermal: Not Classified; Inhalation: Cat. 4	Not Classified	Not Classified	Not Classified	Not Classified	Not Classified	Not Classified	Prop 65[4]	Not Classified	Cat. 1	Not Listed	Listed for Developmental Toxicity
			55.00	5	0	0	0	0	0	0	25	0	25	0	Covered under Reproductive/ Developmental Toxicity
	Epikure™ 3271 (CAS No. 111-40-0, 50-70%)	4.08		Oral: Cat. 4; Dermal: Cat. 4; Inhalation: Cat. 2	Not Classified	Cat. 1	Cat. 1B	Not Classified	Cat. 3 (respiratory irritation)	Not Classified	Not Classified	Not Classified	Cat. 1B	Not Listed	Not Listed
			90.00	50	0	5	5	0	5	0	0	0	25	0	N/A
	Epikure™ 3271 (CAS No. 80-05-7, 25-35%)			Oral/Dermal/Inhalation: Not Classified	Not Classified	Cat. 1	Not Classified	Not Classified	Cat. 3 (respiratory irritation)	Not Classified	Cat. 1B/Prop 65	Not Classified	Cat. 1	Present	Listed for Reproductive Toxicity
			110.00	0	0	5	0	0	5	0	50	0	25	25	Covered under Reproductive/ Developmental Toxicity
	Total Human Health Score		**755.00**												
DuPont Patent No. WO 2013/101682 A1 Example Formulation	Tetrafunctional Acrylate (CAS No. 94108-97-1)	30.04		Not classified (exposure route not specified in Pharos)	Cat. 2	Cat. 2B	Not Classified	Not Classified	Cat. 3 (not specified)	Not Classified	Not Classified	DG	Not Classified	Not Listed	Not Listed
			125.00	0	75	10	0	0	15	0	0	25	0	0	N/A
	Difunctional Acrylate A (CAS No. 55818-57-0)	10.94		Oral/Dermal/Inhalation: Not Classified	DG	Not Classified	Not Classified	Not Classified	Not Classified	Not Classified	Not Classified	Cat. 1A (Pharos)	Cat. 1	Not Listed	Not Listed
			75.00	0	25	0	0	0	0	0	0	25	25	0	N/A
	Trimethylolpropane tris(Acetoacetonate) (CAS No. 22208-25-9)	32.26		Oral: Not Classified; Dermal: Not Classified; Inhalation: DG	DG	Not Classified	Not Classified	Not Classified	DG	DG	DG	DG	Not Classified	Not Listed	Not Listed
			175.00	0	50	0	0	0	25	25	50	25	0	0	N/A
	Total Human Health Score		**375.00**												
Dow Patent No. WO 2015/142564 A1 Example Formulation	Polycarbamate (no CAS No., reaction product)	45.00		DG for all endpoints. Unable to assess due to generic name and lack of CAS No.											
			335.00	25	50	25	25	50	25	25	50	25	25	10	
	1,3- and 1,4-Cyclohexane Dicarboxaldehyde (CHDA) (EC No. 482-020-3 , no CAS No., assuming purified grade)	33.50		Oral: Cat. 4; Dermal: Not Classified; Inhalation: Not Classified	Not Classified	Cat. 1	Not Classified	Not Classified	Cat. 3 (respiratory irritation)	Not Classified	Not Classified	Not Classified	Cat. 1B	Not Listed	Not Listed
			100.00	10	0	25	0	0	15	0	0	0	50	0	0
	Total Human Health Score		**435.00**												
DuPont Patent No. WO 2018/005142 A1 Example Formulation	Polycarbamate 2 (no CAS No., reaction product)	~31.60		DG for all endpoints. Unable to assess due to generic name and lack of CAS No.											
			335.00	25	50	25	25	50	25	25	50	25	25	10	
	1,3- and 1,4-Cyclohexane Dicarboxaldehyde (CHDA) (EC No. 482-020-3, no CAS No., assuming purified grade)	~36.41		Oral: Cat. 4; Dermal: Not Classified; Inhalation: Not Classified	Not Classified	Cat. 1	Not Classified	Not Classified	Cat. 3 (respiratory irritation)	Not Classified	Not Classified	Not Classified	Cat. 1B	Not Listed	Not Listed
			100.00	10	0	25	0	0	15	0	0	0	50	0	N/A
	Total Human Health Score		**435.00**												
Lower-Exposure Approaches (Also Priority Products)															
Firestone/Gaco Profill System™	Unreacted MDI (CAS Nos. 101-68-8 and 26447-40-5)/pMDI (CAS No. 9016-87-9)	50.00		Oral: Not Classified; Dermal: Not Classified; Inhalation: Cat. 4	Cat. 2[3]	Cat. 2	Cat. 2	Not Classified	Cat. 3 (respiratory irritation)	Cat. 2 (inhalation)	Not Classified	Cat. 1	Cat. 1B	Not Listed	Not Listed
			245.00	10	75	10	10	0	15	25	0	50	50	0	N/A
	beta-D-Fructofuranosyl alpha-D-glucopyranoside/Sucrose (CAS No. 57-50-1)	15.00		Not Classified (based on US FDA GRAS)	Not Classified (based on US FDA GRAS)	Not Classified (based on US FDA GRAS)	Not Classified (based on US FDA GRAS)	Not Classified (based on *in vitro* studies)	Not Classified (based on US FDA GRAS)	Not Classified (based on US FDA GRAS)	Not Classified (based on US FDA GRAS)	DG	Not Classified (based on US FDA GRAS)	Not Listed	Not Listed
			10.00	0	0	0	0	0	0	0	0	10	0	0	0
	Total Human Health Score		**255.00**												

Priority Product and Potential Alternatives	Functional Ingredients	Percentage of Product (A- and B-Sides Combined)	Score	Group A Endpoints											
				Acute Mammalian Toxicity	Carcinogenicity	Eye Irritation/ Corrosion	Skin Irritation/ Corrosion (Dermatotoxicity)	Germ Cell Mutagenicity	Target Organ Toxicity – Single Exposure	Target Organ Toxicity – Repeated Exposure	Reproductive/ Developmental Toxicity	Sensitizer – Respiration	Sensitizer – Skin	Endocrine Disruptor (EU Priority List)	California Proposition 65
High-Volume Low-Pressure (HVLP) Systems (*e.g.,* Nitrosys/ICP HandiFoam HVLP MD 2.0)	Unreacted MDI (CAS Nos. 101-68-8 and 26447-40-5)/pMDI (CAS No. 9016-87-9)	50.00		Oral: Not classified; Dermal: Not Classified; Inhalation: Cat. 4	Cat. 2[3]	Cat. 2	Cat. 2	Not classified	Cat. 3 (respiratory irritation)	Cat. 2 (inhalation)	Not classified	Cat. 1	Cat. 1B	Not Listed	Not Listed
			245.00	10	75	10	10	0	15	25	0	50	50	0	N/A
	Polymer in Polyester Polyol (TSCA-exempted polymer, CAS No. may not have been assigned)	~8 (based on generic formula ratio)		DG for all endpoints. Unable to assess due to generic name and lack of CAS No.											
			120.00	5	25	5	5	25	5	5	25	5	5	10	N/A
	Diethylene Glycol in Polyester Polyol (CAS No. 111-46-6)	2.50		Oral: Cat. 4; Dermal: Not Classified; Inhalation: Not Classified	Not Classified	Not Classified	Not Classified	Not Classified	Not Classified	Not Classified	Not Classified	DG	Not Classified	Not Listed	Not Listed
			10.00	5	0	0	0	0	0	0	0	5	0	0	N/A
	Aromatic Amino Polyether Polyol (*e.g.* , oxirane, 2-methyl-, polymer with oxirane, ether with 2,6-bis((bis(2-hydroxyethyl)amino)methyl)-4-branched nonylphenol [CAS No. 940912-28-7])	16.80 (based on generic formula)		DG	DG	DG	DG	DG	DG	DG	DG	DG	DG	Not Listed	Not Listed
			145.00	10	25	10	10	25	10	10	25	10	10	0	N/A
	Total Human Health Score		**520.00**												
BASF Patent No. 9592516 B2 Example Formulation[5]	Unreacted MDI (CAS Nos. 101-68-8 and 26447-40-5)/pMDI (CAS No. 9016-87-9)	50.00		Oral: Not Classified; Dermal: Not Classified; Inhalation: Cat. 4	Cat. 2[3]	Cat. 2	Cat. 2	Not Classified	Cat. 3 (respiratory irritation)	Cat. 2 (inhalation)	Not Classified	Cat. 1	Cat. 1B	Not Listed	Not Listed
			245.00	10	75	10	10	0	15	25	0	50	50	0	N/A
	Diethylene Glycol (CAS No. 111-46-6)	22.50		Oral: Cat. 4; Dermal: Not Classified; Inhalation: Not Classified	Not Classified	Not Classified	Not Classified	Not Classified	Not Classified	Not Classified	Not Classified	DG	Not Classified	Not Listed	Not Listed
			15.00	5	0	0	0	0	0	0	0	10	0	0	N/A
	Polyether Polyol (*e.g.* , oxirane, 2-methyl-, polymer with oxirane, ether with 1,2,3-propanetriol [3:1] [CAS No. 9082-00-2])	12.50		Oral: Cat. 4; Dermal: DG; Inhalation: DG	DG	Cat. 2	DG	DG	DG	DG	DG	DG	DG	Not Listed	Not Listed
			135.00	5	25	5	10	25	10	10	25	10	10	0	N/A
	Polyether Polyol (*e.g.* , sucrose, propylene oxide [CAS No. 9049-71-2])	5.00		Oral: Not Classified; Dermal: Not Classified; Inhalation: DG	Not Classified	Not Classified	Not Classified	Not Classified	Not Classified	Not Classified	Not Classified	DG	Not Classified	Not Listed	Not Listed
			5.00	0	0	0	0	0	0	0	0	5	0	0	0
	Total Human Health Score		**400.00**												
BASF Patent No. WO 2019/089237 A1 Example Formulation	Unreacted MDI (CAS Nos. 101-68-8 and 26447-40-5)/pMDI (CAS No. 9016-87-9)	50.00		Oral: Not Classified; Dermal: Not Classified; Inhalation: Cat. 4	Cat. 2[3]	Cat. 2	Cat. 2	Not Classified	Cat. 3 (respiratory irritation)	Cat. 2 (inhalation)	Not Classified	Cat. 1	Cat. 1B	Not Listed	Not Listed
			245.00	10	75	10	10	0	15	25	0	50	50	0	N/A
	Aromatic Polyester (*e.g.* , Terol 258) (cannot identify CAS No.)	22.56		DG for all endpoints. Unable to assess due to generic name and lack of CAS No.											
			155.00	10	25	10	10	25	10	10	25	10	10	10	N/A
	GSP-280 Polyol (CAS No. 26301-10-0, 80-90%)	11.87		DG for all endpoints.										Not Listed	Not Listed
			145.00	10	25	10	10	25	10	10	25	10	10	0	N/A
	GSP-280 Polyol (CAS No. 9082-00-2, 5-20%)			Oral: Cat. 4; Dermal: DG; Inhalation: DG	DG	Cat. 2A	DG	DG	DG	DG	DG	DG	DG	Not Listed	Not Listed
			110.00	5	25	5	5	25	5	5	25	5	5	0	N/A
	Total Human Health Score		**655.00**												

Notes:

Cat. = Category; CLP = Classification, Labelling, and Packaging Regulation; DG = Data Gap; ECHA = European Chemicals Agency; EU = European Union; GHS = Globally Harmonized System of Classification and Labelling of Chemicals; GRAS = Generally Recognized as Safe; MDI = Methylene Diphenyl Diisocyanate; pMDI = Polymeric Methylene Diphenyl Diisocyanate; SPF = Spray Polyurethane Foam; TSCA = Toxic Substances Control Act; US FDA = US Food and Drug Administration.

Data for Group A endpoints, except endocrine disruptor and California Proposition 65, were obtained primarily *via* ECHA dossiers (ECHA, 2020). If a dossier has both a EU CLP Annex VI classification and a self-classification, the self-classifications were recorded in this table. For pMDI/MDI, we used the ECHA classifications of CAS No. 101-68-8, because it is a more complete ECHA dossier compared to that of CAS No. 26447-40-5. In addition, the hazard classifications in the two dossiers match. The ECHA dossier for pMDI (CAS No. 9016-87-9) links to that of MDI (CAS No. 26447-40-5). For those chemicals (*i.e.* , CAS Nos. 9082-00-2, 940912-28-7, 25085-99-8, 94108-97-1, 57-50-1, 26301-10-0, and 9082-00-2) that do not have ECHA dossiers (ECHA, 2020), Pharos (Healthy Building Network, 2020) information was used. Note that unverified hazard list information from Pharos was not used. Sucrose does not have an ECHA dossier or a Pharos entry; thus, US FDA GRAS status documentation (UL LLC, 2020) and a Cosmetic Ingredient Review article (Fiume *et al.* , 2019) were used. The EU's Endocrine Disruptor Priority List and California Proposition 65 Lists were used to inform the Endocrine Disruptor and California

(1) This table presents the hazards of the individual product ingredients, which do not indicate the hazards of the actual final product when fully cured and installed.

(2) No generic formulation exists for Group 4: High Pressure, Closed Cell, 3 lbs/ft^3.

(3) MDI is required by law in the EU to be classified as Carcinogen Category 2; however, US authoritative agencies such as the California Environmental Protection Agency Office of Environmental Health Hazard Assessment (CalOEHHA) and the National Toxicology Program (NTP) have not classified MDI or pMDI as a carcinogens. Additionally, the US EPA Integrated Risk Information System (IRIS) and the International Agency for Research on Cancer (IARC) have determined MDI and pMDI to be "not classifiable" as to human carcinogenicity based on the available evidence (US EPA, 1998; IARC, 1999). Lastly, the EU's Category 2 H351 assignment was converted from an older R40 Category 3 assignment using the same data.

(4) The ECHA dossier for CAS No. 1134-23-2 did not classify for reproductive/developmental toxicity (ECHA, 2020); however, it is listed under California Proposition 65 as a developmental hazard (UL LLC, 2020). As a result, it is evaluated as a developmental toxicant in this table.

(5) The BASF Patent No. 9592516 B2 example formulation proposes multiple options for each functional polyols a) polyethylene terephthalate, diethylene glycol, phthalic acid, and/or terephthalic acid; b) phenol or nonylphenol, formaldehyde, and/or amines, one or more with propylene oxide and optionally ethylene oxide; and c) sucrose, glycerin, propylene glycol, and/or propylene oxide. A specific polyol was selected in each group to assess in this table (*i.e.* , diethylene glycol, sucrose propylene oxide, and oxirane, 2-methyl-, polymer with oxirane, ether with 1,2,3-propanetriol [3:1]).

Legend for Group A Hazards:

Categories were assigned according to ECHA dossiers (ECHA, 2020) and Pharos (Healthy Building Network, 2020).

Cat. 1	Category 1 is most hazardous classification for all endpoints. For a minority of endpoints (*i.e.* , acute mammalian and chronic aquatic toxicity), Category 4 is the least hazardous. For the rest of the endpoints, excluding physical endpoints, Category 2 is the least hazardous. "Not Classified" indicates no hazard according to endpoint-specific GHS criteria. Specific color-coding varies by health endpoint according to GreenScreen Chemical Hazard Criteria Section V - Annex 1 (Clean Production Action, 2018).
Cat. 2	
Cat. 3	
Cat. 4	
Not Classified/Not Listed	
DG	

Table 5.3 Functional Ingredient-specific Human Health Hazards (Group B Endpoints)[1]

Priority Product and Potential Alternatives	Functional Ingredients	Percentage of Product (A- and B-Sides Combined)	Group B Endpoints										
			Respiratory Toxicity	Cardiovascular Toxicity	Epigenetic Toxicity	Hematotoxicity	Reactive in Biological Systems	Hepatotoxicity and Digestive System Toxicity	Immunotoxicity	Musculoskeletal Toxicity	Nephrotoxicity	Neurotoxicity	Ototoxicity
Priority Product[3]													
MDI/pMDI in all Priority Products	Unreacted MDI (CAS Nos. 101-68-8 and 26447-40-5) and pMDI (CAS No. 9016-87-9)	46.25-50	Adverse pulmonary effects observed	No relevant adverse effects observed	Not genotoxic; no other relevant data found	No relevant adverse effects observed	DG	No relevant adverse effects observed	Respiratory and dermal sensitizer	DG	No relevant adverse effects observed	No relevant adverse effects observed	DG
Generic Formula for Group 1 (Low Pressure, Various Densities)	Polymer in Polyester Polyol (TSCA-exempted polymer, CAS No. may not have been assigned, 70%)	11.5	DG for all endpoints. Unable to assess due to generic name and lack of CAS No.										
	Diethylene Glycol in Polyester Polyol (CAS No. 111-46-6, 30%)		DG	No relevant adverse effects observed	Not genotoxic; no other relevant data found	Slight changes in blood chemistry observed at high dose, but dossier did not classify	DG	Increased liver weight was observed, but dossier did not classify	Not a dermal sensitizer.. No other relevant data found.	No relevant adverse effects observed	Permanent renal failure at high doses due to metabolite, but dossier did not classify	Neurotoxicity observed in poisoning cases, but dossier did not classify	DG
	Option A: Polyether Polyol (*e.g.* , oxirane, 2-methyl-, polymer with oxirane, ether with 1,2,3-propanetriol [3:1] [CAS No. 9082-00-2])	11.5	DG for all endpoints. No ECHA dossier available. No repeat dose data identified in other regulatory sources.										
	Option B: Polyether Polyol (*e.g.* , sucrose, propylene oxide [CAS No. 9049-71-2])	11.5	DG	No relevant adverse effects observed	DG	Conflicting and slight changes in blood chemistry of questionable toxicological significance observed at high dose, but dossier did not classify	DG	No relevant adverse effects observed	Not a dermal sensitizer.. No other relevant data found.	No relevant adverse effects observed	No relevant adverse effects observed	No relevant adverse effects observed	DG
Generic Formula for Group 2 (High Pressure, Open Cell, 0.5 lb/ft^3)	**Option A:** Polyether Polyol (*e.g.* , oxirane, 2-methyl-, polymer with oxirane, ether with 1,2,3-propanetriol [3:1] [CAS No. 9082-00-2])	17	DG for all endpoints. No ECHA dossier available. No repeat dose data identified in other regulatory sources.										
	Option B: Polyether Polyol (*e.g.* , sucrose, propylene oxide [CAS No. 9049-71-2])	17	DG	No relevant adverse effects observed	DG	Conflicting and slight changes in blood chemistry of questionable toxicological significance observed at high dose, but dossier did not classify	DG	No relevant adverse effects observed	Not a dermal sensitizer.. No other relevant data found.	No relevant adverse effects observed	No relevant adverse effects observed	No relevant adverse effects observed	DG
Generic Formula for Group 3 (High Pressure, Medium Density, Closed Cell, 2 lbs/ft^3)	Polymer in Polyester Polyol (TSCA-exempted polymer, CAS may not have been assigned, 70%)	18.2	DG for all endpoints. Unable to assess due to generic name and lack of CAS No.										
	Diethylene Glycol in Polyester Polyol (CAS No. 111-46-6, 30%)		DG	No relevant adverse effects observed	Not genotoxic; no other relevant data found	Slight changes in blood chemistry observed at high dose, but dossier did not classify	DG	Increased liver weight was observed, but dossier did not classify	Not a dermal sensitizer.. No other relevant data found.	No relevant adverse effects observed	Permanent renal failure at high doses due to metabolite, thus dossier did not classify	Neurotoxicity observed in poisoning cases, but dossier did not classify	DG
	Aromatic Amino Polyether Polyol (*e.g.* , oxirane, 2-methyl-, polymer with oxirane, ether with 2,6-bis((bis(2-hydroxyethyl)amino)methyl)-4-branched nonylphenol [CAS No. 940912-28-7])	16.81	DG for all endpoints. No ECHA dossier available. No repeat dose data identified in other regulatory sources.										
Non-MDI-based Alternative Formulations													
Firestone/Gaco Canary™ Example Formulation	Sucrose Acetoacetate (No CAS No. identified)	26.09	DG for all endpoints. Unable to assess due to generic name and lack of CAS No.										
	Glycerine Acetoacetate (No CAS No. identified)	26.09	DG for all endpoints. Unable to assess due to generic name and lack of CAS No.										
	Meta Xylene Diamine (MXDA) (CAS No. 1477-55-0)	15.48	Minimal and transient respiratory effects observed, but dossier did not classify	DG	Not genotoxic; no other relevant data found	Slight changes in blood chemistry observed at high dose, but dossier did not classify	DG	Changes in the digestive system are secondary to corrosivity of substance; no relevant adverse liver effects observed	Dermal sensitizer	No relevant adverse effects observed	No relevant adverse effects observed	Decreased locomotion observed at high dose near lethal dose; however, dossier did not classify	DG
	Dytek® A (2-Methyl-1,5-diaminopentane) (CAS No. 15520-10-2)	10.26	Reversible respiratory tract lesions and irritation observed, but dossier did not classify	DG	Not genotoxic; no other relevant data found	Transient hemoconcentration due to dehydration and decrease in lymphocytes due to stress	DG	Non-treatment-related decrease in liver weight observed	Not a dermal sensitizer.. No other relevant data found.	DG	No relevant adverse effects observed	DG	DG
Hybrid Coatings Technologies/Nanotech Industries Green Polyurethane™ Example Formulation	DER 331, Bisphenol-A Epoxy Resin (CAS No. 25085-99-8)	81.80	DG for all endpoints. No ECHA dossier available. No information available in Pharos.										
	Ancamine 2678 (No CAS No. identified)	14.30	DG for all endpoints. Unable to assess due to generic name and lack of CAS No.										
Owens Corning Example Formulation	DER 331, Bisphenol-A Epoxy Resin (CAS No. 25085-99-8)	45.73	DG for all endpoints. No ECHA dossier available. No repeat dose data identified in other regulatory sources.										
	Epon™ 8111, Multifunctional Epoxy Resin (CAS No. 25068-38-6, ~50%)	16.34	DG	DG	Not genotoxic; no other relevant data found.	DG	DG	DG	Dermal sensitizer	DG	Adverse effects seen at high-dose *via* read-across, but dossier	DG	DG
	Epon™ 8111, Multifunctional Epoxy Resin (CAS No. 15625-89-5, ~50%)		DG	DG	Not genotoxic; no other relevant data found.	DG	DG	DG	Dermal sensitizer	DG	Adverse effects seen at high-dose *via* read-across, but dossier	DG	DG
	Cycloate A (CAS No. 1134-23-2)/Ancamine 2678 (no CAS No. identified, thus not evaluated)	17.49	DG	DG	No genotoxicity study available	No relevant adverse effects observed	DG	DG	Dermal sensitizer	DG	DG	DG	DG
	Epikure™ 3271 (CAS No. 111-40-0, 50-70%)	4.08	No relevant adverse effects observed	Decreased heart organ weight, but dossier did not classify	Not genotoxic; no other relevant data found.	Minimal and non-treatment-related increase in mean corpuscular volume and mean corpuscular hemoglobin were observed	DG	Increased liver weight, but dossier did not classify	Dermal sensitizer	DG	Increased kidney weight, but dossier did not classify	DG	DG
	Epikure™ 3271 (CAS No. 80-05-7, 25-35%)		Respiratory tract irritation and inflammation observed	Atrophy and vacuolation of myocytes in the heart were observed at the high dose	Not genotoxic; no other relevant data found.	No relevant adverse effects observed	DG	Increased liver weight and multinucleated giant hepatocytes, but dossier did not classify	Dermal sensitizer	DG	Increased kidney weight, but dossier did not classify	Increased brain weight observed, but dossier did not classify	DG

Priority Product and Potential Alternatives	Functional Ingredients	Percentage of Product (A- and B-Sides Combined)	Group B Endpoints										
			Respiratory Toxicity	Cardiovascular Toxicity	Epigenetic Toxicity	Hematotoxicity	Reactive in Biological Systems	Hepatotoxicity and Digestive System Toxicity	Immunotoxicity	Musculoskeletal Toxicity	Nephrotoxicity	Neurotoxicity	Ototoxicity
DuPont Patent No. WO 2013/101682 A1 Example Formulation	Tetrafunctional Acrylate (CAS No. 94108-97-1)	30.04	DG for all endpoints. No ECHA dossier available. No repeat dose data identified in other regulatory sources.										
	Difunctional Acrylate A (CAS No. 55818-57-0)	10.94	DG	No relevant adverse effects observed	Not genotoxic; no other relevant data found.	Changes in blood cell counts found, but dossier did not classify	DG	Microscopic effects found at a high dose in liver, but dossier did not classify	Dermal sensitizer	DG	No relevant adverse effects observed	Reduction in locomotive activity at a high dose, but dossier did not classify	DG
	Trimethylolpropane tris(Acetoacetonate) (CAS No. 22208-25-9)	32.26	DG	DG	Not genotoxic; no other relevant data found.	DG	DG	DG	Not a dermal sensitizer.. No other relevant data found.	DG	DG	DG	DG
Dow Patent No. WO 2015/142564 A1 Example Formulation	Polycarbamate (no CAS No., reaction product)	45.00	DG for all endpoints. Unable to assess due to generic name and lack of CAS No.										
	1,3- and 1,4-Cyclohexane Dicarboxaldehyde (CHDA) (EC No. 482-020-3 , no CAS No., assuming purified grade)	33.50	Respiratory tract irritation and decrease respiratory rate observed	Reduced heart weight at high dose, but dossier did not classify	Not genotoxic; no other relevant data found.	Hematological changes observed at high dose, but dossier did not classify	DG	Significant local effects to the stomach and digestion system and increased liver weight and hypertrophy observed, but dossier did not classify	Dermal sensitizer	No relevant adverse effects observed	Increased kidney to body weight at high dose, but dossier did not classify	Motor activity decreased at high dose, but dossier did not classify	No relevant adverse effects observed
DuPont Patent No. WO 2018/005142 A1 Example Formulation	Polycarbamate 2 (no CAS No., reaction product)	~31.60	DG for all endpoints. Unable to assess due to generic name and lack of CAS No.										
	1,3- and 1,4-Cyclohexane Dicarboxaldehyde (CHDA) (EC No. 482-020-3, no CAS No., assuming purified grade)	~36.41	Respiratory tract irritation and decrease respiratory rate observed	Reduced heart weight at high dose, but dossier did not classify	Not genotoxic; no other relevant data found.	Hematological changes observed at high dose, but dossier did not classify	DG	Significant local effects to the stomach and digestion system and increased liver weight and hypertrophy observed, but dossier did not classify	Respiratory and dermal sensitizer	No relevant adverse effects observed	Increased kidney to body weight at high dose, but dossier did not classify	Motor activity decreased at high dose, but dossier did not classify	No relevant adverse effects observed
Lower-Exposure Approaches (Also Priority Products)													
Firestone/Gaco Profill System™	Unreacted MDI (CAS Nos. 101-68-8 and 26447-40-5) and pMDI (CAS No. 9016-87-9)	50.00	Adverse pulmonary effects observed	No relevant adverse effects observed	Not genotoxic; no other relevant data found.	No relevant adverse effects observed	DG	No relevant adverse effects observed	Respiratory and dermal sensitizer	DG	No relevant adverse effects observed	No relevant adverse effects observed	DG
	beta-D-Fructofuranosyl alpha-D-glucopyranoside/Sucrose (CAS No. 57-50-1)	15.00	Respiratory tract irritation observed in workers	No relevant adverse effects expected due to US FDA GRAS status	Not genotoxic; no other relevant data found.	No relevant adverse effects expected due to US FDA GRAS status	DG	No relevant adverse effects expected due to US FDA GRAS status	DG	No relevant adverse effects expected due to US FDA GRAS status	No relevant adverse effects expected due to US FDA GRAS status	No relevant adverse effects expected due to US FDA GRAS status	DG
High-Volume Low-Pressure (HVLP) Systems (*e.g.*, Nitrosys/ICP HandiFoam HVLP MD 2.0)	Unreacted MDI (CAS Nos. 101-68-8 and 26447-40-5) and pMDI (CAS No. 9016-87-9)	50.00	Adverse pulmonary effects observed	No relevant adverse effects observed	Not genotoxic; no other relevant data found.	No relevant adverse effects observed	DG	No relevant adverse effects observed	Respiratory and dermal sensitizer	DG	No relevant adverse effects observed	No relevant adverse effects observed	DG
	Polyester Polyol (in low-pressure Priority Products) (TSCA-exempted polymer, CAS No. may not have been assigned)	~8 (based on generic formula ratio)	DG for all endpoints. Unable to assess due to generic name and lack of CAS No.										
	Diethylene glycol (CAS No. 111-46-6)	2.50	DG	No relevant adverse effects observed	Not genotoxic; no other relevant data found.	Slight changes in blood chemistry observed at high dose, but dossier did not classify	DG	Increased liver weight was observed, but dossier did not classify	Respiratory and dermal sensitizer	No relevant adverse effects observed	Permanent renal failure at high doses due to metabolite, thus dossier did not classify	Neurotoxicity observed in poisoning cases, but dossier did not classify	DG
	Aromatic Amino Polyether Polyol (*e.g.* , oxirane, 2-methyl-, polymer with oxirane, ether with 2,6-bis((bis(2-hydroxyethyl)amino)methyl)-4-branched nonylphenol [CAS No. 940912-28-7])	16.80 (based on generic formula)	DG for all endpoints. No ECHA dossier available. No repeat dose data identified in other regulatory sources.										
BASF Patent No. 9592516 B2 Example Formulation[4]	Unreacted MDI (CAS Nos. 101-68-8 and 26447-40-5) and pMDI (CAS No. 9016-87-9)	50.00	Adverse pulmonary effects observed	No relevant adverse effects observed	Not genotoxic; no other relevant data found.	No relevant adverse effects observed	DG	No relevant adverse effects observed	Respiratory and dermal sensitizer	DG	No relevant adverse effects observed	No relevant adverse effects observed	DG
	Diethylene Glycol (CAS No. 111-46-6)	22.50	DG	No relevant adverse effects observed	Not genotoxic; no other relevant data found.	Slight changes in blood chemistry observed at high dose, but dossier did not classify	DG	Increased liver weight was observed, but dossier did not classify	Not a dermal sensitizer.. No other relevant data found.	No relevant adverse effects observed	Permanent renal failure at high doses due to metabolite, thus dossier did not classify	Neurotoxicity observed in poisoning cases, but dossier did not classify	DG
	Polyether Polyol (*e.g.* , oxirane, 2-methyl-, polymer with oxirane, ether with 1,2,3-propanetriol [3:1] [CAS No. 9082-00-2])	12.50	DG for all endpoints. No ECHA dossier available. No repeat dose data identified in other regulatory sources.										
	Polyether Polyol (*e.g.* , sucrose, propylene oxide [CAS No. 9049-71-2])	5.00	DG	No relevant adverse effects observed	DG	Conflicting and slight changes in blood chemistry of questionable toxicological significance observed at high dose, but dossier did not classify	DG	No relevant adverse effects observed	Not a dermal sensitizer.. No other relevant data found.	No relevant adverse effects observed	No relevant adverse effects observed	No relevant adverse effects observed	DG
BASF Patent No. WO 2019/089237 A1 Example Formulation	Unreacted MDI (CAS Nos. 101-68-8 and 26447-40-5) and pMDI (CAS No. 9016-87-9)	50.00	Adverse pulmonary effects observed	No relevant adverse effects observed	Not genotoxic; no other relevant data found.	No relevant adverse effects observed	DG	No relevant adverse effects observed	Respiratory and dermal sensitizer	DG	No relevant adverse effects observed	No relevant adverse effects observed	DG
	Aromatic Polyester (*e.g.* , Terol 258) (cannot identify CAS No.)	22.56	DG for all endpoints. Unable to assess due to generic name and lack of CAS No.										
	GSP-280 Polyol (CAS No. 26301-10-0, 80-90%)	11.87	DG for all endpoints. No ECHA dossier available. No repeat dose data identified in other regulatory sources.										
	GSP-280 Polyol (CAS No. 9082-00-2, 5-20%)		DG for all endpoints. No ECHA dossier available. No repeat dose data identified in other regulatory sources.										

Notes:

DG = Data Gap; ECHA = European Chemicals Agency; GRAS = Generally Recognized as Safe; IMAP = Inventory Multi-tiered Assessment and Prioritisation; MDI = Methylene Diphenyl Diisocyanate; pMDI = Polymeric Methylene Diphenyl Diisocyanate; SPF = Spray Polyurethane Foam; TSCA = Toxic Substances Control Act; US FDA = US Food and Drug Administration.

Data for Group B hazards are from mainly from ECHA dossiers (ECHA, 2020). Australia IMAP assessments were used for Epon™ 8111, Multifunctional Epoxy Resin (CAS No. 25068-38-6) (Australia Dept. of Health, 2015), and Epon™ 8111, Multifunctional Epoxy Resin (CAS No. 15625-89-5) (Australia Dept. of Health, 2017). US FDA GRAS status (UL LLC, 2209) and a Cosmetic Ingredient Review article were used (Fiume *et al.* , 2019) for sucrose.

(1) This table presents the hazards of the individual product ingredients, which may not reflect the hazards of the actual final product when fully cured and installed.

(2) Although genotoxicity generally implies changes in the DNA sequence, which is outside the scope of epigenetic toxicity, it also implies a potential for interaction with DNA, so it is listed here given that more direct data on epigenetic effects are lacking.

(3) No generic formulation exists for Group 4: High Pressure, Closed Cell SPF (3 lbs/ft^3).

(4) The BASF Patent No. 9592516 B2 example formulation proposes multiple options for each functional polyols: (a) polyethylene terephthalate, diethylene glycol, phthalic acid, and/or terephthalic acid; (b) phenol or nonylphenol, formaldehyde, and/or amines, one or more with propylene oxide and optionally ethylene oxide; and (c) sucrose, glycerin, propylene glyco, and/or propylene oxide. A specific polyol was selected in each group to assess in this table (*i.e* ., diethylene glycol, sucrose propylene oxide, and oxirane, 2-methyl-, polymer with oxirane, ether with 1,2,3-propanetriol [3:1]).

Legend for Group B Hazards:

Potential Concern	Qualitative review of data in ECHA dossiers (ECHA, 2020), IMAP (Australia Dept. of Health, 2015, 2017), US FDA GRAS status (UL LLC, 2020), and a Cosmetic Ingredient Review article (Fiume *et al.* , 2019) implying the effect is associated with the chemical at some level.
No Relevant Adverse Effects Observed	
DG	

Table 5.4 Functional Ingredient-specific Environmental and Physical Hazards[1]

Priority Product and Potential Alternatives	Functional Ingredients	Percentage of Product (A- and B-Sides Combined)	Environmental Score	Physical Score	Environmental					Physical			
					Aquatic Toxicity – Acute	Aquatic Toxicity – Chronic	Persistent	Bioaccumulation	Terrestrial Ecotoxicity (from Pharos Only)	Global Warming Potential	Ozone Depleting Potential	CAA VOC Contributing to Smog Formation	Flammability
Priority Product[2]													
pMDI/MDI in Priority Product	Unreacted MDI (CAS Nos. 101-68-8 and 26447-40-5) and pMDI (CAS No. 9016-87-9)	46.25-50			Not Classified	Not Classified	Hydrolysis half-life for pMDI is 20 hours, thus MDI is not persistent per 22 CCR § 69405.3[3]	No (due to high reactivity)	DG	No	No	VOC and not on 40 CFR § 51.100 exempted list[4]	Not Classified
			0	50	0	0	0	0	0	0	0	50	0
Generic Formula for Group 1 (Low Pressure, Various Densities)	Polymer in Polyester Polyol (TSCA-exempted polymer, CAS No. may not have been assigned, 70%)	11.5			DG	DG	Likely Persistent (polymer)	Likely No (polymer)	DG	No[5]	No[6]	DG	DG
			70	5	10	10	50	0	0	0	0	5	0
	Diethylene Glycol in Polyester Polyol (CAS No. 111-46-6, 30%)				Not Classified	Not Classified	Readily biodegradable in water	No	DG	No	No	Not a VOC (low vapor pressure)	Not Classified
			0	0	0	0	0	0	0	0	0	0	0
	Option A: Polyether Polyol (*e.g.* , oxirane, 2-methyl-, polymer with oxirane, ether with 1,2,3-propanetriol [3:1] [CAS No. 9082-00-2])	11.5			Likely Not Classified (polymer)	Likely Not Classified (polymer)	Likely Persistent (polymer)	Likely No (polymer)	Moderate	No	No	DG	DG
			100	10	0	0	50	0	50	0	0	10	0
	Option B: Polyether Polyol (*e.g.* , sucrose, propylene oxide [CAS No. 9049-71-2])	11.5			Not Classified	Not Classified	Readily biodegradable in water	No	DG	No	No	Not a VOC (low vapor pressure)	Not Classified
			0	0	0	0	0	0	0	0	0	0	0
	Total Environmental and Physical Scores		**70-170**	**55-65**									
Generic Formula for Group 2 (High Pressure, Open Cell, 0.5 lb/ft^3)	**Option A:** Polyether Polyol (*e.g.* , oxirane, 2-methyl-, polymer with oxirane, ether with 1,2,3-propanetriol [3:1] [CAS No. 9082-00-2])	17			Likely Not Classified (polymer)	Likely Not Classified (polymer)	Likely Persistent (polymer)	Likely No (polymer)	Moderate	No	No	DG	DG
			100	10	0	0	50	0	50	0	0	10	0
	Option B: Polyether Polyol (*e.g.* , sucrose, propylene oxide [CAS No. 9049-71-2])	17			Not Classified	Not Classified	Readily biodegradable in water	No	DG	No	No	Not a VOC (low vapor pressure)	Not Classified
			0	0	0	0	0	0	0	0	0	0	0
	Total Environmental and Physical Scores		**0-100**	**50-60**									
Generic Formula for Group 3 (High Pressure, Medium Density, Closed Cell, 2 lbs/ft^3)	Polymer in Polyester Polyol (TSCA-exempted polymer, CAS No. may not have been assigned, 70%)	18.2			DG	DG	Likely Persistent (polymer)	Likely No (polymer)	DG	No[5]	No[6]	DG	DG
			100	10	25	25	50	0	0	0	0	10	0
	Diethylene Glycol in Polyester Polyol (CAS No. 111-46-6, 30%)				Not Classified	Not Classified	Readily biodegradable in water	No	DG	No	No	Not a VOC (low vapor pressure)	Not Classified
			0	0	0	0	0	0	0	0	0	0	0
	Aromatic Amino Polyether Polyol (*e.g.* , oxirane, 2-methyl-, polymer with oxirane, ether with 2,6-bis((bis(2-hydroxyethyl) amino)methyl)-4-branched nonylphenol [CAS No. 940912-28-7])	16.81			Likely Not Classified (polymer)	Likely Not Classified (polymer)	Likely Persistent (polymer)	Likely No (polymer)	DG	No	No	DG	DG
			50	10	0	0	50	0	0	0	0	10	0
	Total Environmental and Physical Scores		**150**	**70**									
Non-MDI-based Alternative Formulations													
Firestone/Gaco Canary™ Example Formulation	Sucrose Acetoacetate (No CAS No. identified)	26.09			DG for all endpoints. Unable to assess due to generic name and lack of CAS No.					No[5]	No[6]	DG	DG
			100	10	25	25	25	25	0	0	0	10	0
	Glycerine Acetoacetate (No CAS No. identified)	26.09			DG for all endpoints. Unable to assess due to generic name and lack of CAS No.					No[5]	No[6]		
			100	10	25	25	25	25	0	0	0	10	0
	Meta Xylene Diamine (MXDA) (CAS No. 1477-55-0)	15.48			Not Classified	Cat. 3	Inherently biodegradable in water	No	DG	No	No	Not a VOC (low vapor pressure)	Not Classified
			20	0	0	10	10	0	0	0	0	0	0
	Dytek® A (2-Methyl-1,5-diaminopentane) (CAS No. 15520-10-2)	10.26			Not Classified	Not Classified	Readily biodegradable in water	No (due to high hydrophilicity)	DG	No	No	VOC and not on 40 CFR § 51.100 exempted list	Not Classified
			0	25	0	0	0	0	0	0	0	25	0
	Total Environmental and Physical Scores		**220**	**45**									
Hybrid Coatings Technologies/Nanotech Industries Green Polyurethane™ Example Formulation	DER 331, Bisphenol-A Epoxy Resin (CAS No. 25085-99-8)	81.8			Cat. 1 (Pharos)	DG	Persistent based on modeling (Pharos)	Likely No (polymer)	DG	No	No	Not a VOC (low vapor pressure)	DG
			225	0	100	75	50	0	0	0	0	0	0
	Ancamine 2678 (No CAS No. identified)	14.30			DG for all endpoints. Unable to assess due to generic name and lack of CAS No.								
			100	10	25	25	25	25	0	0	0	10	0
	Total Environmental and Physical Scores		**325**	**10**									
Owens Corning Example Formulation	DER 331, Bisphenol-A Epoxy Resin (CAS No. 25085-99-8)	45.7			Cat. 1 (Pharos)	DG	Persistent based on modeling (Pharos)	Likely No (polymer)	DG	No	No	Not a VOC (low vapor pressure)	DG
			175	0	75	50	50	0	0	0	0	0	0
	Epon™ 8111, Multifunctional Epoxy Resin (CAS No. 25068-38-6, ~50% of 16.34%)	16.34			Not Classified	Cat. 2	Persistent based on biodegradation study. Hydrolysis observed within 28 days	No	DG	No	No	Not a VOC (low vapor pressure)	Not Classified
			60	0	0	10	50	0	0	0	0	0	0
	Epon™ 8111, Multifunctional Epoxy Resin (CAS No. 15625-89-5, ~50% of 16.34%)				Cat. 1	Cat. 1	Readily biodegradable in water	No (modeled)	DG	No	No	Not a VOC (low vapor pressure)	Not Classified
			50	0	25	25	0	0	0	0	0	0	0
	Cycloate A (CAS No. 1134-23-2)/Ancamine 2678 (no CAS No. identified, thus not evaluated)	17.49			Cat. 1	Cat. 1	Persistent in water (modeled)	No (modeled)	DG	No	No	Not a VOC (low vapor pressure)	Not Classified
			150	0	50	50	50	0	0	0	0	0	0
	Epikure™ 3271 (CAS No. 111-40-0, 50-70% of 4.08%)	4.08			Not Classified	Not Classified	Readily biodegradable in water	No	Moderate	No	No	VOC and not on 40 CFR § 51.100 exempted list	Not Classified
			25	10	0	0	0	0	25	0	0	10	0
	Epikure™ 3271 (CAS No. 80-05-7, 25-35% of 4.08%)				Not Classified	Cat. 2	Readily biodegradable in water	No	DG	No	No	Not a VOC (low vapor pressure)	Not Classified
			10	0	0	10	0	0	0	0	0	0	0
	Total Environmental and Physical Scores		**470**	**10**									

					Environmental					Physical			
Priority Product and Potential Alternatives	**Functional Ingredients**	**Percentage of Product (A- and B-Sides Combined)**	**Environmental Score**	**Physical Score**	**Aquatic Toxicity – Acute**	**Aquatic Toxicity – Chronic**	**Persistent**	**Bioaccumulation**	**Terrestrial Ecotoxicity (from Pharos Only)**	**Global Warming Potential**	**Ozone Depleting Potential**	**CAA VOC Contributing to Smog Formation**	**Flammability**
DuPont Patent No. WO 2013/101682 A1 Example Formulation	Tetrafunctional Acrylate (CAS No. 94108-97-1)	30.04			Cat. 2	Cat. 1	Persistent (Pharos)	No (Pharos)	DG	No	No	Not a VOC (low vapor pressure)	Not Classified
			175	0	50	75	50	0	0	0	0	0	0
	Difunctional Acrylate A (CAS No. 55818-57-0)	10.94			Not Classified	Not Classified	Inherently biodegradable in water	No	DG	No	No	Not a VOC (low vapor pressure)	Not Classified
			10	0	0	0	10	0	0	0	0	0	0
	Trimethylolpropane tris(Acetoacetonate) (CAS No. 22208-25-9)	32.26			Not Classified	Not Classified	Inherently biodegradable in water	No	DG	No	No	Not a VOC (low vapor pressure)	Not Classified
			10	0	0	0	10	0	0	0	0	0	0
	Total Environmental and Physical Scores		**195**	**0**									
Dow Patent No. WO 2015/142564 A1 Example Formulation	Polycarbamate (no CAS No., reaction product)	45.00			DG for all endpoints. Unable to assess due to generic name and lack of CAS No.					No[5]	No[6]	DG	DG
			150	25	50	50	25	25	0	0	0	25	0
	1,3- and 1,4-Cyclohexane Dicarboxaldehyde (CHDA) (EC No. 482-020-3 , no CAS No., assuming purified grade)	33.50			Not Classified	Cat. 3	Readily biodegradable in water	No	DG	No	No	Not a VOC assuming purified grade (low vapor pressure)	Not Classified
			25	0	0	25	0	0	0	0	0	0	0
	Total Environmental and Physical Scores		**175**	**25**									
DuPont Patent No. WO 2018/005142 A1 Example Formulation	Polycarbamate 2 (no CAS No., reaction product)	~31.60			DG for all endpoints. Unable to assess due to generic name and lack of CAS No.					No[5]	No[6]	DG	DG
			150	25	50	50	25	25	0	0	0	25	0
	1,3- and 1,4-Cyclohexane Dicarboxaldehyde (CHDA) (EC No. 482-020-3 , no CAS No. identified, assuming purified grade)	~36.41			Not Classified	Cat. 3	Readily biodegradable in water	No	DG	No	No	Not a VOC assuming purified grade (low vapor pressure)	Not Classified
			25	0	0	25	0	0	0	0	0	0	0
	Total Environmental and Physical Scores		**175**	**25**									
Lower-Exposure Approaches (Also Priority Products)													
Firestone/Gaco Profill System™	Unreacted MDI (CAS Nos. 101-68-8 and 26447-40-5) and pMDI (CAS No. 9016-87-9)	50.00			Not Classified	Not Classified	Hydrolysis half-life for pMDI is 20 hours, thus MDI is not persistent per 22 CCR § 69405.3[3]	No (due to high reactivity)	DG	No	No	VOC and not on 40 CFR § 51.100 exempted list[4]	Not Classified
			0	50	0	0	0	0	0	0	0	50	0
	beta-D-Fructofuranosyl alpha-D-glucopyranoside/Sucrose (CAS No. 57-50-1)	15.00			Not Classified (modeled)	Not Classified (modeled)	Readily biodegradable in water (modeled)	No	DG	No	No	Not a VOC (solid at 25C)	Not Classified (based on professional judgement)
			0	0	0	0	0	0	0	0	0	0	0
	Total Environmental and Physical Scores		**0**	**50**									
High-Volume Low-Pressure (HVLP) Systems (*e.g.,* Nitrosys/ICP HandiFoam HVLP MD 2.0)	Unreacted MDI (CAS Nos. 101-68-8 and 26447-40-5) and pMDI (CAS No. 9016-87-9)	50.00			Not Classified	Not Classified	Hydrolysis half-life for pMDI is 20 hours, thus MDI is not persistent per 22 CCR § 69405.3[3]	No (due to high reactivity)	DG	No	No	VOC and not on 40 CFR § 51.100 exempted list[4]	Not Classified
			0	50	0	0	0	0	0	0	0	50	0
	Polyester Polyol (in low-pressure Priority Products) (TSCA-exempted polymer, CAS No. may not have been assigned)	~8 (based on generic formula ratio)			DG	DG	Likely Persistent (polymer)	Likely No (polymer)	DG	No[5]	No[6]	DG	DG
			70	5	10	10	50	0	0	0	0	5	0
	Diethylene Glycol (CAS No. 111-46-6)	2.50			Not Classified	Not classified	Readily biodegradable in water	No	DG	No	No	Not a VOC (low vapor pressure)	Not Classified
			0	0	0	0	0	0	0	0	0	0	0
	Aromatic Amino Polyether Polyol (*e.g.* , oxirane, 2-methyl-, polymer with oxirane, ether with 2,6-bis((bis(2-hydroxyethyl) amino)methyl)-4-branched nonylphenol [CAS No. 940912-28-7])	16.80 (based on generic formula)			Likely Not Classified (polymer)	Likely Not Classified (polymer)	Likely Persistent (polymer)	Likely No (polymer)	DG	No	No	DG	DG
			50	10	0	0	50	0	0	0	0	10	0
	Total Environmental and Physical Scores		**120**	**65**									
BASF Patent No. 9592516 B2 Example Formulation[7]	Unreacted MDI (CAS Nos. 101-68-8 and 26447-40-5) and pMDI (CAS No. 9016-87-9)	50.00			Not Classified	Not Classified	Hydrolysis half-life for pMDI is 20 hours, thus MDI is not persistent per 22 CCR § 69405.3[3]	No (due to high reactivity)	DG	No	No	VOC and not on 40 CFR § 51.100 exempted list[4]	Not Classified
			0	50	0	0	0	0	0	0	0	50	0
	Diethylene Glycol (CAS No. 111-46-6)	22.50			Not Classified	Not Classified	Readily biodegradable in water	No	DG	No	No	Not a VOC (low vapor pressure)	Not Classified
			0	0	0	0	0	0	0	0	0	0	0
	Polyether Polyol (*e.g.* , oxirane, 2-methyl-, polymer with oxirane, ether with 1,2,3-propanetriol [3:1] [CAS No. 9082-00-])	12.50			Likely Not Classified (polymer)	Likely Not Classified (polymer)	Likely Persistent (polymer)	Likely No (polymer)	Moderate	No	No	DG	DG
			100	10	0	0	50	0	50	0	0	10	0
	Polyether Polyol (*e.g.* , sucrose, propylene oxide [CAS No. 9049-71-2])	5.00			Not Classified	Not Classified	Readily biodegradable in water	No	DG	No	No	Not a VOC (low vapor pressure)	Not Classified
			0	0	0	0	0	0	0	0	0	0	0
	Total Environmental and Physical Scores		**100**	**60**									

Priority Product and Potential Alternatives	Functional Ingredients	Percentage of Product (A- and B-Sides Combined)	Environmental Score	Physical Score	Environmental					Physical			
					Aquatic Toxicity – Acute	Aquatic Toxicity – Chronic	Persistent	Bioaccumulation	Terrestrial Ecotoxicity (from Pharos Only)	Global Warming Potential	Ozone Depleting Potential	CAA VOC Contributing to Smog Formation	Flammability
BASF Patent No. WO 2019/089237 A1 Example Formulation	Unreacted MDI (CAS Nos. 101-68-8 and 26447-40-5) and pMDI (CAS No. 9016-87-9)	50.00			Not Classified	Not Classified	Hydrolysis half-life for pMDI is 20 hours, thus MDI is not persistent per 22 CCR § 69405.3[3]	No (due to high reactivity)	DG	No	No	VOC and not on 40 CFR § 51.100 exempted list[4]	Not Classified
			0	50	0	0	0	0	0	0	0	50	0
	Aromatic Polyester (*e.g.* , Terol 258) (no CAS No. identified)	22.56			DG for all endpoints. Unable to assess due to generic name and lack of CAS No.					No[5]	No[6]	DG	DG
			100	10	25	25	25	25	0	0	0	10	0
	GSP-280 Polyol (CAS No. 26301-10-0, 80-90%)	11.87			DG	DG	Persistent (Pharos)	Likely No (polymer)	DG	No	No	DG	DG
			100	10	25	25	50	0	0	0	0	10	0
	GSP-280 Polyol (CAS No. 9082-00-2, 5-20%)				DG	DG	Persistent (Pharos)	Likely No (polymer)	Moderate (Pharos)	No	No	DG	DG
			95	5	10	10	50	0	25	0	0	5	0
	Total Environmental and Physical Scores		**295**	**75**									

Notes:

BCF = Bioconcentration Factor; CAA = Clean Air Act; DG = Data Gap; ECHA = European Chemicals Agency; GHS = Globally Harmonized System of Classification and Labelling of Chemicals; GWP = Global Warming Potential; K_{ow} = Octanol-Water Partition Coefficient; MDI = Methylene Diphenyl Diisocyanate; ODP = Oxygen-Depleting Potential; pMDI = Polymeric Methylene Diphenyl Diisocyanate; SPF = Spray Polyurethane Foam; TSCA = Toxic Substances Control Act; US EPA = United States Environmental Protection Agency; VOC = Volatile Organic Compound.

Data from ECHA dossiers (ECHA, 2020) were used to inform Aquatic Toxicity, Persistence, Bioaccumulation, and Flammability. Ingredients are considered persistent if 0 to <20% of the ingredient degrades within 28 days, inherently biodegradable if 20 to <60% of the ingredient degrades within 28 days, and readily biodegradable if 60 to 100% of the ingredient degrades within 28 days. Ingredients are considered not bioaccumulative if BCF is <500 or log K_{ow} is <4. For those chemicals (*i.e.* , CAS Nos. 9082-00-2, 940912-28-7, 25085-99-8, 94108-97-1, 57-50-1, 26301-10-0, and 9082-00-2) that do not have ECHA dossiers (ECHA, 2020), Pharos (Healthy Building Network, 2020) was used. US EPA's list of ozone-depleting substances (US EPA, 2018b) was used to evaluate ODP. Pharos (Healthy Building Network, 2020) was used to inform terrestrial toxicity. GWP was evaluated using Table 8.a.1 of the IPCC 5th Technical Report (IPCC, 2013). VOCs were considered chemicals with vapor pressures equal to or greater than 0.1 mm mercury (Hg) based on criteria in CARB (2009). Additionally, we noted whether the functional ingredient is listed as a substance exempted under 40 CFR § 51.100 (CARB, 2009). US EPA Epi Suite modeling was used to inform sucrose

(1) This table presents the hazards of the individual product ingredients, which do not indicate the hazards of the actual final product when fully cured and installed.

(2) No generic formulation exists for Group 4: High Pressure, Closed Cell, 3 lbs/ft^3.

(3) Following California regulations (*i.e.* , 22 CCR § 69405.3; CalDTSC, 2012b), MDI is not considered persistent based on the half-life in water of a surrogate, pMDI. The hydrolysis half-lives of pMDI averaged around 20 hours (0.83 day) (ECHA, 2020), which is less than the persistence criterion of 40 days according to 22 CCR § 69405.3. The main hydrolysis product of MDI and pMDI is solid and inert polyurea, which is persistent based on its reported half-life (Sendijarevic *et al.* , 2004). Similarly, an evaluating Member State Competent Authority in the EU reviewed the ECHA dossier of MDI and concluded "that the substance itself is not persistent in the environment due to its hydrolytical unstability, but the hydrolysis products can be considered persistent" (Estonia, Health Board, 2018)

(4) The unreacted MDI in the Priority Products is currently classified under the Clean Air Act as such (US EPA, 2018a), but based on their own research, the REs do not consider MDI to be a VOC that contributes to ozone and smog formation. In California, CARB exempts low-vapor pressure VOCs from the California VOC regulations, such as those with a vapor pressure less than 0.1 mm Hg at 20°C or a boiling point greater than 216°C (CARB, 2020). Therefore, MDI is considered a low-vapor-pressure VOC with negligible potential to contribute to tropospheric ozone production due to MDI's vapor pressure of 0.000021 mg Hg at 25°C (Olf, 2018) and boiling point of >300°C (ECHA, 2020).

(4) For the GWP of functional ingredients that lacked data or were described more generically (*i.e.* , by class of compound), we considered whether they are gases and whether they were chlorinated or fluorinated. Chemicals that did not meet these criteria were considered to have negligible GWP.

(5) For the ODP of those functional ingredients that were described more generically (*i.e.* , by class of compound), we considered whether the functional ingredient was a gas and whether it is chlorinated or brominated (*i.e.* , based on the name provided). If a chemical had no data on this endpoint and was not a gas or likely to be chlorinated or brominated, we assumed it would not have ODP.

(6) The BASF Patent No. 9592516 B2 example formulation proposes multiple options for each functional polyols: (a) polyethylene terephthalate, diethylene glycol, phthalic acid, and/or terephthalic acid; (b) phenol or nonylphenol, formaldehyde, and/or amines, one or more with propylene oxide and optionally ethylene oxide; and (c) sucrose, glycerin, propylene glyco, and/or propylene oxide. A specific polyol was selected in each group to assess in this table (*i.e.* , diethylene glycol, sucrose propylene oxide, and oxirane, 2-methyl-, polymer with oxirane, ether with 1,2,3-propanetriol [3:1]).

Legend:

Categories assigned according to ECHA dossiers (ECHA, 2020) and Pharos (Healthy Building Network, 2020). Specific color coding varies by endpoint according to GreenScreen Chemical Hazard Criteria Section V - Annex 1 (Clean Production Action, 2018).

Cat. 1	Category 1 is most hazardous classification for all endpoints. For a minority of endpoints (*i.e.* , chronic aquatic toxicity), Category 4 is the least hazardous. For the rest of the endpoints, excluding physical endpoints, Category 2 is the least hazardous. Not classified indicated no hazard according to endpoint-specific GHS criteria.
Cat. 2	
Cat. 3	
Not Classified/No	
DG	

Table 5.5 Summary of Main Transformation Products from Ingredients

Priority Product and Alternative Formulations	Starting Chemical		Main Transformation Pathway Summary from ECHA REACH Dossier (ECHA, 2020)	Main Transformation Products (ECHA, 2020)			ECHA (2020) REACH Dossier GHS Classification(s) of the Transformation Product	EU PBT List (UL LLC, 2020)	CA Toxic Air Contaminant List (UL LLC, 2020)	CA Proposition 65 (UL LLC, 2020)	Vapor Pressure (Saturated, mm Hg at 25°C) (ECHA, 2020)	Water Solubility (mg/L at 25 °C) (ECHA, 2020)	Log K_{oc} (ECHA, 2020)	Log K_{ow} (ECHA, 2020)
	Name	CAS No.		Pathway	Name	CAS No.								
Priority Product	Unreacted MDI/pMDI	101-68-8/ 906-87-9	In the environment, the main removal pathway of MDI and pMDI is hydrolysis. The isocyanate reacts with water to form an intermediary amine, such as MDA. However, this intermediary amine immediately reacts with other MDI present to form an insoluble polyurea. MDA is not listed as a potential transformation product due to its intermediary nature. Hydrolysis occurs in soil or water media, and MDI does not partition into a vapor phase. Transformation products are provided by the ECHA dossier (ECHA, 2020). MDI hydrolyzes in sludge. However, information on the exact transformation products in sludge is not available.	Hydrolysis	Reaction Product of Diphenylmethanediisocyanate, Octylamine, 4-Ethoxyaniline, and Ethylenediamine	EC No. 430-750-8, No CAS No. identified	Aquatic Chronic Tox. 4	Not listed	Not listed	Not listed	<2E-12	<1 (20°C)	DG	>6
				Hydrolysis	MDI Oligomers	25686-28-6	Acute Tox. 4; Skin Irrit. 2; Eye Irrit. 2; Resp. Sens. 1; Skin Sens. 1B; Carc. 2; STOT Single Exp. 3; STOT Rep. Exp. 2	Not listed	Not listed	Not listed	7.13E-05	5.17E-05	DG	8.56
				Hydrolysis	Insoluble Polyurea	Cannot identify	DG	Not listed	Not listed	Not listed	DG	DG	DG	DG
				Hydrolysis	DG	DG	DG	N/A	N/A	N/A	DG	DG	DG	DG
	Option A for Polyether Polyol (*e.g.* , oxirane, 2-methyl-, polymer with oxirane, ether with 1,2,3-propanetriol [3:1])	9082-00-2	No information available.	DG	DG	DG	DG	N/A	N/A	N/A	DG	DG	DG	DG
	Option B for Polyether Polyol (*e.g.* , sucrose, propylene oxide)	9049-71-2	Substance degrades in water, however, no information on transformation products is available. Additionally, substance is susceptible to phototransformation in air based on AOPWIN modeling, nutno information on transformation products is available. The estimated half-life in air for components of this substance is between 1.5 to 2.9 hours.	Phototransformation in Air	DG	DG	DG	N/A	N/A	N/A	DG	DG	DG	DG
				Degradation in Water	DG	DG	DG	N/A	N/A	N/A	DG	DG	DG	DG
	Polymer in Polyester Polyol (TSCA-exempted polymer, CAS No. may not have been assigned, 70%)	No CAS No. identified	DG for all endpoints. Unable to assess due to generic name and lack of CAS No.								DG	DG	DG	DG
	Diethylene Glycol in Polyester Polyol (30%)	111-46-6	Substance will phototransform in air with an estimated half life of 17.24 hours based on AOPWIN calculations. Substance will also degrade in water. However, transformation products were not reported for either pathway.	Phototransformation in Air	DG	DG	DG	N/A	N/A	N/A	DG	DG	DG	DG
				Degradation in Water	DG	DG	DG	N/A	N/A	N/A	DG	DG	DG	DG
	Aromatic Amino Polyether Polyol (*e.g.* , oxirane, 2-methyl-, polymer with oxirane, ether with 2,6-bis((bis(2-hydroxyethyl)amino)methyl)-4-branched nonylphenol)	940912-28-7	No information available.	DG	DG	DG	DG	N/A	N/A	N/A	DG	DG	DG	DG
Firestone/Gaco Canary™ Example Formulation	Sucrose Acetoacetate	No CAS No. identified	DG for all endpoints. Unable to assess due to generic name and lack of CAS No.											
	Glycerine Acetoacetate	No CAS No. identified	DG for all endpoints. Unable to assess due to generic name and lack of CAS No.											
	Meta Xylene Diamine (MXDA)	1477-55-0	MXDA biodegrades in water. However, transformation products were not reported. The K_{oc} value of 3.11 (calculated from the measured K_{ow}) suggests partitioning into soil or organic matter.	Activated Sludge	DG	DG	DG	N/A	N/A	N/A	DG	DG	DG	DG
	Dytek® A (2-Methyl-1,5-diaminopentane)	15520-10-2	Ingredient is biodegradable in water. However, transformation products were not reported.	Biodegradation	DG	DG	DG	N/A	N/A	N/A	DG	DG	DG	DG
Hybrid Coatings Technologies/Nanotech Industries Green Polyurethane™ Example Formulation	DER 331, Bisphenol-A Epoxy Resin	25085-99-8	No data were identified for transformation products.	DG	DG	DG	DG	N/A	N/A	N/A	DG	DG	DG	DG
	Ancamine 2678	No CAS No. identified	DG for all endpoints. Unable to assess due to generic name and lack of CAS No.											

Priority Product and Alternative Formulations	Starting Chemical Name	Starting Chemical CAS No.	Main Transformation Pathway Summary from ECHA REACH Dossier (ECHA, 2020)	Main Transformation Products (ECHA, 2020) Pathway	Name	CAS No.	ECHA (2020) REACH Dossier GHS Classification(s) of the Transformation Product	EU PBT List (UL LLC, 2020)	CA Toxic Air Contaminant List (UL LLC, 2020)	CA Proposition 65 (UL LLC, 2020)	Vapor Pressure (Saturated, mm Hg at 25°C) (ECHA, 2020)	Water Solubility (mg/L at 25 °C) (ECHA, 2020)	Log K_{oc} (ECHA, 2020)	Log K_{ow} (ECHA, 2020)
Owens Corning Example Formulation	DER 331, Bisphenol-A Epoxy Resin	25085-99-8	No data were identified for transformation products.	DG	DG	DG	DG	N/A	N/A	N/A	DG	DG	DG	DG
	Epon™ 8111, Multifunctional Epoxy Resin	25068-38-6	Ingredient undergoes hydrolysis. However, exact transformation products were not reported.	Hydrolysis	DG	DG	DG	N/A	N/A	N/A	DG	DG	DG	DG
	Epon™ 8111, Multifunctional Epoxy Resin	15625-89-5	Main transformation pathway is hydrolysis. However, exact transformation products were not reported.	Hydrolysis	DG	DG	DG	N/A	N/A	N/A	DG	DG	DG	DG
	Cycloate A/Ancamine 2678	1134-23-2/ No CAS No. identified	Substance is stable to hydrolysis and photolysis in water. Substance is not biodegradable in water.	No Transformation Products at Environmental pH and Temperatures	DG	DG	DG	N/A	N/A	N/A	DG	DG	DG	DG
	Epikure™ 3271	111-40-0	Substance will phototransform in air with an estimated half life of 2.6 hours. Substance will degrade in water, soil and activated sludge. However, transformation products were not reported for either pathway.	Phototransformation in Air	DG	DG	DG	N/A	N/A	N/A	DG	DG	DG	DG
				Biodegradation in Water, Soil and Activated Sludge	DG	DG	DG	N/A	N/A	N/A	DG	DG	DG	DG
	Epikure™ 3271	80-05-7	BPA degrades by photolysis after exposure to air and in the presence of hydroxy radicals. Bound BPA residue can also react under anoxic conditions and form new products once re-exposed to oxygen. Transformation products are provided based on reported literature (ECHA, 2020; Im and Loffler, 2016). BPA is metabolized by microbes, algae and fungi in oxic conditions (ECHA, 2020; Im and Loffler, 2016).	Microbial	4-Hydroxybenzaldehyde	123-08-0	Eye Damage 1	Not listed	Not listed	Not listed	3E-05 (converted from 0.0041 Pa)	7770 (20°C)	DG	1.3 (23°C)
				Microbial	4-Hydroxybenzoate/ 4-Hydroxybenzoic Acid	456-23-5/ 99-96-7	Eye Damage 1; STOT Single Exp. Oral 3; STOT Single Exp. Inhal. 3	Not listed	Not listed	Not listed	1.58E-7 (converted from 2.11 x 10E-05 Pa)	4870 (20°C)	"[L]ow potential for adsorption" (ECHA, 2020)	0.878 (22°C, pH = 3.5, [non-ionized form], <0.3 [ionized form])
				Microbial	4-Hydroxyacetophenone	99-93-4	Eye Irrit. 2A; Aquatic Chronic Tox. 3	Not listed	Not listed	Not listed	1.5E-5 (20°C)	10000 (22°C)	2.03	1.35
				Microbial	2,2-bis(4-hydroxyphenyl)-1-propanol	142648-65-5	DG	Not listed	Not listed	Not listed	DG	DG	DG	DG
				Microbial	4-Hydroxyphenacyl Alcohol	5706-85-4	DG	Not listed	Not listed	Not listed	DG	DG	DG	DG
				Nitration	Dinitrobisphenol A	5329-21-5	DG	Not listed	Not listed	Not listed	DG	DG	DG	DG
				Fungal/Photolysis	Phenol	108-95-2	Acute Tox. Oral 3; Acute Tox. Derm. 3; Acute Tox. Inhal. 3; Skin Corr. 1B; Muta. 2; STOT Rep. Exp. 2; Skin Corr. 1B; Skin Irrit. 2; Eye Irrit. 2	Not listed	Listed	Not listed	0.15 (20°C) (converted from 0.2 hPa)	84,000 (20°C)	1.92 (20°C) (converted from 82.8 L/kg)	1.47 (30°C)
				Fungal	4-Isopropenylphenol	4286-23-1	DG	Not listed	Not listed	Not listed	DG	DG	DG	DG
				Fungal/Photolysis	4-Isopropylphenol	99-89-8	Acute Tox. Oral 4; Acute Tox. Derm. 4; Acute Tox. Inhal. 4; Skin Corr 1B	Not listed	Not listed	Not listed	0.015 (converted from 2.01 Pa)	DG	DG	DG
				Fungal	Hexestrol	84-16-2	DG	Not listed	Not listed	Not listed	DG	DG	DG	DG
				Algal/Plant	BPA-mono-O-beta-D-glucopyranoside	Cannot identify	DG	N/A	N/A	N/A	DG	DG	DG	DG
				Algal/Plant	BPA-mono-O-beta-D galactopyranoside	Cannot identify	DG	N/A	N/A	N/A	DG	DG	DG	DG
				Plant	BPA Mono-beta-D-gentiobioside	Cannot identify	DG	N/A	N/A	N/A	DG	DG	DG	DG
				Anoxic Oxidation with MnO_2	4-(2-Hydroxypropan-2-yl)phenol	2948-47-2	DG	Not listed	Not listed	Not listed	DG	DG	DG	DG
				Photolysis	Semi-quinone Derivative of BPA	Cannot identify	DG	N/A	N/A	N/A	DG	DG	DG	DG
DuPont Patent No. WO 2013/101682 A1 Example Formulation	Tetrafunctional Acrylate	94108-97-1	No information available.	DG	DG	DG	DG	N/A	N/A	N/A	DG	DG	DG	DG
	Difunctional Acrylate A	55818-57-0	Substance hydrolyzes in neutral (pH = 7) and basic (pH = 9) conditions. Potential hydrolysis transformation products are provided based on professional judgment. Substance is biodegradable in activated sludge. However, transformation products in activated sludge are not available.	Hydrolysis/Microbial	BPA	80-05-7	Eye Damage 1; Skin Sens. 1; Repr. 1B; STOT Single Exp. 1; Aquatic Chronic Tox. 2	Not listed	Listed	Listed as reproductive toxicant	3.09E-09	298	2.89-3.93	3.4
				Hydrolysis	Bisphenol A epichlorohydrin polymer	25068-38-6	Skin Irrit. 2; Eye Irrit. 2; Skin Sens. 1; Aquatic Chronic Tox. 2	Not listed	Not listed	Not listed	6.72E-08	6.9	DG	3.242
				Hydrolysis	Bisphenol A bis(2,3-Dihydroxypropyl) Ether	5581-32-8	DG	Not listed	Not listed	Not listed	DG	DG	DG	DG
				Biodegradation in Activated Sludge	DG	DG	DG	N/A	N/A	N/A	DG	DG	DG	DG
	Trimethylolpropane tris(Acetoacetonate)	22208-25-9	Substance hydrolyzes under basic conditions and is biodegradable in water. However, transformation products were not reported.	Hydrolysis	DG	DG	DG	N/A	N/A	Not listed	DG	DG	DG	DG
				Biodegradation in Water	DG	DG	DG	N/A	N/A	N/A	DG	DG	DG	DG
Dow Patent No. WO 2015/142564 A1 Example Formulation	Polycarbamate	No CAS No. identified	DG for all endpoints. Unable to assess due to generic name and lack of CAS No.											
	1,3- and 1,4-Cyclohexane Dicarboxaldehyde (CHDA)	EC No. 482-020-3, No CAS No. identified	Substance is degradable in water and activated sludge based on three experimental studies. However, no transformation products were reported. Substance is expected to phototransform in air, with an estimated half-life of 0.2 days for a mixture of 1,3- and 1,4-cyclohexanedicarboxyaldehyde, calculated using the Atmospheric Oxidation Program in US EPA's EPI Suite software. However, no transformation products were reported.	Phototransformation in Air	DG	DG	DG	N/A	N/A	N/A	DG	DG	DG	DG
				Degradation in Water or Activated Sludge	DG	DG	DG	N/A	N/A	N/A	DG	DG	DG	DG

Priority Product and Alternative Formulations	Starting Chemical		Main Transformation Pathway Summary from ECHA REACH Dossier (ECHA, 2020)	Main Transformation Products (ECHA, 2020)			ECHA (2020) REACH Dossier GHS Classification(s) of the Transformation Product	EU PBT List (UL LLC, 2020)	CA Toxic Air Contaminant List (UL LLC, 2020)	CA Proposition 65 (UL LLC, 2020)	Vapor Pressure (Saturated, mm Hg at 25°C) (ECHA, 2020)	Water Solubility (mg/L at 25 °C) (ECHA, 2020)	Log K_{oc} (ECHA, 2020)	Log K_{ow} (ECHA, 2020)
	Name	CAS No.		Pathway	Name	CAS No.								
DuPont Patent No. WO 2018/005142 A1 Example Formulation	Polycarbamate 2	No CAS No. identified	DG for all endpoints. Unable to assess due to generic name and lack of CAS No.											
	1,3- and 1,4-Cyclohexane Dicarboxaldehyde (CHDA)	EC No. 482-020-3, No CAS No. identified	Substance is degradable in water and activated sludge based on three experimental studies. However, no transformation products were reported. Substance is expected to phototransform in air, with an estimated half-life of 0.2 days for a mixture of 1,3- and 1,4-cyclohexanedicarboxyaldehyde, calculated using the Atmospheric Oxidation Program in US EPA's EPI Suite software. However, no transformation products were reported.	Phototransformation in Air	DG	DG	DG	N/A	N/A	N/A	DG	DG	DG	DG
				Degradation in Water or Activated Sludge	DG	DG	DG	N/A	N/A	N/A	DG	DG	DG	DG
Firestone/Gaco Profill System™	Unreacted MDI/pMDI	101-68-8/ 906-87-9	In the environment, the main removal pathway of MDI and pMDI is hydrolysis. The isocyanate reacts with water to form an intermediary amine, such as MDA. However, this intermediary amine immediately reacts with other MDI present to form an insoluble polyurea. MDA is not listed as a potential transformation product due to its intermediary nature. Hydrolysis occurs in soil or water media, and MDI does not partition into a vapor phase. Transformation products are provided by the ECHA dossier (ECHA, 2020). MDI hydrolyzes in sludge. However, information on the exact transformation products in sludge is not available.	Hydrolysis	Reaction Product of Diphenylmethanediisocyanate, Octylamine, 4-Ethoxyaniline, and Ethylenediamine	EC No. 430-750-8, No CAS No. identified	Aquatic Chronic Tox. 4	Not listed	Not listed	Not listed	<2E-12	<1 (20°C)	DG	>6
				Hydrolysis	MDI Oligomers	25686-28-6	Acute Tox. 4; Skin Irrit. 2; Eye Irrit. 2; Resp. Sens. 1; Skin Sens. 1B; Carc. 2; STOT Single Exp. 3; STOT Rep. Exp. 2	Not listed	Not listed	Not listed	7.13E-05	5.17E-05	DG	8.56
				Hydrolysis	Insoluble Polyurea	Cannot identify	DG	Not listed	Not listed	Not listed	DG	DG	DG	DG
				Activated Sludge	DG	DG	DG	N/A	N/A	N/A	DG	DG	DG	DG
	beta-D-Fructofuranosyl alpha-D-glucopyranoside/Sucrose	57-50-1	Sucrose hydrolyzes extremely slowly in water. However, it is readily digestible by animals and microbes. Cleaving the glycosidic bond as catalyzed by sucrase enzymes yields glucose and fructose monosaccharides (LibreTexts Chemistry Library, 2015). Potential transformation products are provided based on professional judgement.	Hydrolysis/ Biodegradation	Glucose	2280-44-6	No toxicity expected due to US FDA GRAS status (UL LLC, 2020)	Not listed	Not listed	Not listed	Not applicable (Solid)	1E+6 (US EPA, 2019a)	-1.781 (US EPA, 2019a)	-2.89 (US EPA, 2019a)
				Hydrolysis/ Biodegradation	Fructose	7660-25-5	No toxicity expected due to US FDA GRAS status (UL LLC, 2020)	Not listed	Not listed	Not listed	Not applicable (Solid)	1E+6 (US EPA, 2019a)	-0.936 (US EPA, 2019a)	-1.55 (US EPA, 2019a)
High-Volume Low-Pressure (HVLP) Systems (*e.g.,* Nitrosys/ICP HandiFoam HVLP MD 2.0)	Unreacted MDI/pMDI	101-68-8/ 906-87-9	In the environment, the main removal pathway of MDI and pMDI is hydrolysis. The isocyanate reacts with water to form an intermediary amine, such as MDA. However, this intermediary amine immediately reacts with other MDI present to form an insoluble polyurea. MDA is not listed as a potential transformation product due to its intermediary nature. Hydrolysis occurs in soil or water media, and MDI does not partition into a vapor phase. Transformation products are provided by the ECHA dossier (ECHA, 2020). MDI hydrolyzes in sludge. However, information on the exact transformation products in sludge is not available.	Hydrolysis	Reaction Product of Diphenylmethanediisocyanate, Octylamine, 4-Ethoxyaniline, and Ethylenediamine	EC No. 430-750-8	Aquatic Chronic Tox. 4	Not listed	Not listed	Not listed	<1.5E-14	<1 (20°C)	DG	>6
				Hydrolysis	MDI Oligomers	25686-28-6	Acute Tox. 4; Skin Irrit. 2; Eye Irrit. 2; Resp. Sens. 1; Skin Sens. 1B; Carc. 2; STOT Single Exp. 3; STOT Rep. Exp. 2	Not listed	Not listed	Not listed	7.13E-05	5.17E-05	DG	8.56
				Hydrolysis	Insoluble Polyurea	Cannot identify	DG	Not listed	Not listed	Not listed	DG	DG	DG	DG
				Activated Sludge	DG	DG	DG	N/A	N/A	N/A	DG	DG	DG	DG
	Polymer in Polyester Polyol (TSCA-exempted polymer, CAS No. may not have been assigned, 70%)	No CAS No. identified	DG for all endpoints. Unable to assess due to generic name and lack of CAS No.											
	Diethylene Glycol	111-46-6	Substance will phototransform in air, with an estimated half-life of 17.24 hours based on AOPWIN calculations. Substance will also degrade in water. However, transformation products were not reported for either	Phototransformation in Air	DG	DG	DG	N/A	N/A	N/A	DG	DG	DG	DG
				Degradation in Water	DG	DG	DG	N/A	N/A	N/A	DG	DG	DG	DG
	Aromatic Amino Polyether Polyol (*e.g.* , oxirane, 2-methyl-, polymer with oxirane, ether with 2,6-bis((bis(2-hydroxyethyl)amino)methyl)-4-branched nonylphenol)	940912-28-7	No information available.	DG	DG	DG	DG	N/A	N/A	N/A	DG	DG	DG	DG

Priority Product and Alternative Formulations	Starting Chemical		Main Transformation Pathway Summary from ECHA REACH Dossier (ECHA, 2020)	Main Transformation Products (ECHA, 2020)			ECHA (2020) REACH Dossier GHS Classification(s) of the Transformation Product	EU PBT List (UL LLC, 2020)	CA Toxic Air Contaminant List (UL LLC, 2020)	CA Proposition 65 (UL LLC, 2020)	Vapor Pressure (Saturated, mm Hg at 25°C) (ECHA, 2020)	Water Solubility (mg/L at 25 °C) (ECHA, 2020)	Log K_{oc} (ECHA, 2020)	Log K_{ow} (ECHA, 2020)
	Name	CAS No.		Pathway	Name	CAS No.								
BASF Patent No. 9592516 B2 Example Formulation	Unreacted MDI/pMDI	101-68-8/ 906-87-9	In the environment, the main removal pathway of MDI and pMDI is hydrolysis. The isocyanate reacts with water to form an intermediary amine, such as MDA. However, this intermediary amine immediately reacts with other MDI present to form an insoluble polyurea. MDA is not listed as a potential transformation product due to its intermediary nature. Hydrolysis occurs in soil or water media, and MDI does not partition into a vapor phase. Transformation products are provided by the ECHA dossier (ECHA, 2020). MDI hydrolyzes in sludge. However, information on the exact transformation products in sludge is not available.	Hydrolysis	Reaction Product of Diphenylmethanediisocyanate, Octylamine, 4-Ethoxyaniline, and Ethylenediamine	EC No. 430-750-8, No CAS No. identified	Aquatic Chronic Tox. 4	Not listed	Not listed	Not listed	<2E-12	<1 (20°C)	DG	>6
				Hydrolysis	MDI Oligomers	25686-28-6	Acute Tox. 4; Skin Irrit. 2; Eye Irrit. 2; Resp. Sens. 1; Skin Sens. 1B; Carc. 2; STOT Single Exp. 3; STOT Rep. Exp. 2	Not listed	Not listed	Not listed	7.13E-05	5.17E-05	DG	8.56
				Hydrolysis	Insoluble Polyurea	Cannot identify	DG	Not listed	Not listed	Not listed				
				Activated Sludge	DG	DG	DG	N/A	N/A	N/A	DG	DG	DG	DG
	Diethylene Glycol	111-46-6	Substance will phototransform in air with an estimated half-life of 17.24 hours based on AOPWIN calculations. Substance will also degrade in water. However, transformation products were not reported for either pathway	Phototransformation in Air	DG	DG	DG	N/A	N/A	N/A	DG	DG	DG	DG
				Degradation in Water	DG	DG	DG	N/A	N/A	N/A	DG	DG	DG	DG
	Polyether Polyol (*e.g.* , oxirane, 2-methyl-, polymer with oxirane, ether with 1,2,3-propanetriol [3:1])	9082-00-2	No information available.	DG	DG	DG	DG	N/A	N/A	N/A	DG	DG	DG	DG
	Polyether Polyol (*e.g.* , sucrose, propylene oxide)	9049-71-2	Substance degrades in water, however, no information on transformation products is available. Additionally, substance is susceptible to phototransformation in air based on AOPWIN modeling, but no information on transformation products is available. The estimated half-life in air for components of this substance is between 1.5 to 2.9 hours.	Phototransformation in Air	DG	DG	DG	N/A	N/A	N/A	DG	DG	DG	DG
				Degradation in Water	DG	DG	DG	N/A	N/A	N/A	DG	DG	DG	DG
BASF Patent No. WO 2019/089237 A1 Example Formulation	Unreacted MDI/pMDI	101-68-8/ 906-87-9	In the environment, the main removal pathway of MDI and pMDI is hydrolysis. The isocyanate reacts with water to form an intermediary amine, such as MDA. However, this intermediary amine immediately reacts with other MDI present to form an insoluble polyurea. MDA is not listed as a potential transformation product due to its intermediary nature. Hydrolysis occurs in soil or water media, and MDI does not partition into a vapor phase. Transformation products are provided by the ECHA dossier (ECHA, 2020). MDI hydrolyzes in sludge. However, information on the exact transformation products in sludge is not available.	Hydrolysis	Reaction product of Diphenylmethanediisocyanate, Octylamine, 4-Ethoxyaniline, and Ethylenediamine	EC No. 430-750-8, No CAS No. identified	Aquatic Chronic Tox. 4	Not listed	Not listed	Not listed	<2E-12	<1 (20°C)	DG	>6
				Hydrolysis	MDI Oligomers	25686-28-6	Acute Tox. 4; Skin Irrit. 2; Eye Irrit. 2; Resp. Sens. 1; Skin Sens. 1B; Carc. 2; STOT Single Exp. 3; STOT Rep. Exp. 2	Not listed	Not listed	Not listed	7.13E-05	5.17E-05	DG	8.56
				Hydrolysis	Insoluble Polyurea	Cannot identify	DG	Not listed	Not listed	Not listed	DG	DG	DG	DG
				Activated Sludge	DG	DG	DG	N/A	N/A	N/A	DG	DG	DG	DG
	Aromatic Polyester (*e.g.* , Terol 258)	No CAS No. identified	DG for all endpoints. Unable to assess due to generic name and lack of CAS No.											
	GSP-280 Polyol	26301-10-0	No information available.	DG	DG	DG	DG	N/A	N/A	N/A	DG	DG	DG	DG
	GSP-280 Polyol	9082-00-2	No information available.	DG	DG	DG	DG	N/A	N/A	N/A	DG	DG	DG	DG

Notes:

CA = California; Carc. = Carcinogenicity; CLP = Classification, Labelling and Packaging; Corr. = Corrosion; Derm. = Dermal; DG = Data Gap; EC = European Commission; ECHA = European Chemicals Agency; EU = European Union; Exp. = Exposure; GRAS = Generally Recognized as Safe; Inhal. = Inhalation; Irrit. = Irritation; K_{oc} = Organic Carbon-Water Partition Coefficient; MDA = 4,4'-Methylenedianiline; MDI = Methylene Diphenyl Diisocyanate; MnO_2 = Manganese Dioxide; Muta. = Mutagenicity; N/A = Not Applicable; pMDI = Polymeric Methylene Diphenyl Diisocyanate; P_{ow} = Partition Coefficient; PBT = Persistent, Bioaccumulative, and Toxic; REACH = Registration, Evaluation, Authorisation, and Restriction of Chemicals; Rep. = Repeated; Repr. = Reproduction; Resp. = Respiratory; Sens. = Sensitization; STOT = Single Target Organ Toxicity; Tox. = Toxicity; US FDA = United States Food and Drug Administration.

All data are obtained from ECHA REACH dossiers (ECHA, 2020) unless otherwise noted. If a dossier has both a EU CLP Annex VI classification and a self-classification, the self-classifications were used in this table.

Table 5.6 Scoring Matrix – Human Health Endpoints[1]

Hazard Endpoint	Classification	Concentration in Product			
		<10%	10-29%	30-59%	60-100%
Carcinogenicity	Category 1	100	100	100	100
	Category 2/Prop 65	75	75	75	75
	Data Gap	25	25	50	50
Acute Toxicity	Category 1	75	75	100	100
	Category 2	50	50	75	75
	Category 3	10	25	50	50
	Category 4	5	5	10	10
	Data Gap	5	10	25	50
Mutagenicity[2]	Category 1	50	50	50	50
	Category 2	25	25	25	25
	Data Gap	25	25	50	50
Reproductive Toxicity[2]	Category 1	50	50	50	50
	Category 2/Prop 65	25	25	25	25
	Data Gap	25	25	50	50
Developmental Toxicity[2]	Category 1	50	50	50	50
	Category 2/Prop 65	25	25	25	25
	Data Gap	25	25	50	50
Endocrine[3]	EU Priority List	25	25	25	25
	Data gap	10	10	10	10
Systemic Toxicity/Organ Toxicity – Single Dose[2]	Category 1	25	25	50	50
	Category 2	10	10	25	25
	Category 3	5	5	15	15
	Data Gap	5	10	25	50
Systemic Toxicity/Organ Toxicity – Repeated Dose[2]	Category 1	25	25	50	50
	Category 2	10	10	25	25
	Data Gap	5	10	25	50
Skin Sensitizer[4]	Category 1	25	25	50	50
	Data Gap	5	10	25	50
Respiratory Sensitizer[4]	Category 1	25	25	50	50
	Data Gap	5	10	25	50
Eye Irritant[5]	Category 1	5	10	25	25
	Category 2	5	5	10	10
	Data Gap	5	10	25	25
Skin Irritant[5]	Category 1	5	10	25	25
	Category 2	5	5	10	10
	Data Gap	5	10	25	25
Not Required to Be Classified/Not Listed		0	0	0	0

Notes:

AA = Alternatives Analysis; CSI = Chemical Scoring Index; EU = European Union; GHS = Globally Harmonized System of Classification and Labelling of Chemicals; SCP = Safer Consumer Products.

(1) The original CSI approach did not evaluate products if "more than 30% of [the] product's composition is due to the contribution of components with 'No Data Available,'" with the idea that the product will be re-evaluated at a later time "when more information may be available" (Verslycke *et al*., 2014). We did not follow this approach, because the SCP regulations do not require additional testing, and the timeframe for compliance would not allow for this. Additionally, the original CSI approach does not penalize data gaps on an *endpoint by endpoint* basis. This approach only penalizes a product if <30% of its composition is accounted for by components with data gaps (although the number of data gaps is immaterial), with a singular maximum penalty score of 100 for the environmental categories, 100 for the human health categories, and 50 for the physical categories. If chemicals with data gaps account for ≥30% of a product's composition, the product would be classified as "Do

Not Evaluate." Thus, the CSI approach lacks granularity in terms of how many or which health endpoints have missing data. For this Abridged AA, we added endpoint by endpoint penalty scores for data gaps, which is more conservative than the CSI approach. These data gap scores were assigned based on hazard severity (*i.e.*, the maximum carcinogenicity and mutagenicity data gaps are scored 50 *versus* 10 for endocrine disruption). Also, in general, data gap penalty scores are lower than the Category 1 hazard scores for the same endpoint, and the data gap penalty scores generally decrease with decreasing chemical concentrations, except for some categories of particular concern (*e.g.*, Category 1 carcinogens).

(2) Under the original CSI approach, scores did not differ between these endpoints To provide more granularity in the scoring, for this Abridged AA, we adopted the maximum CSI score for Category 1 hazards for all of the abovementioned hazard endpoints. However, we scaled down to a lower score for subsequent subcategories (approximately 50% of the Category 1 score for Category 2 and so on). This approach is in line with the spirit of the GHS and CSI.

(3) Endocrine hazard was moved from ecological toxicity, under the CSI to human health toxicity, under this Abridged AA's approach. Additionally, we used a score of 25 instead of the original 50 in the CSI for endocrine disruptors, because the EU's Endocrine Disruptor Priority List, which we used in this assessment, is a listing of chemicals with potential endocrine risk that should be explored *via* testing, rather than a list based on studies showing actual effects. In contrast, the maximum score for mutagenicity is 50 and is based on positive findings of a mutagenic effect.

(4) We created separate skin and respiratory sensitization categories from the original CSI's "sensitizer" category, to be consistent with the SCP regulations' required toxicity categories. Additionally, we used a maximum score of 50 instead of the original 25 in the CSI for skin and respiratory sensitization. This is because the original CSI approach was developed for oil and gas applications, in which sensitization was less of an issue. Because sensitization is an important hazard for spray foam insulation and consumer products in general, we increased the maximum score for these endpoints.

(5) We created separate categories for eye and skin irritation from the CSI's "irritant" category, to be more consistent with the SCP regulations' required toxicity categories. We assigned a maximum data gap score of 25 for products in which components with no data account for more than 30% of the composition, matching the score of 25 for Category 1 skin or eye irritants, because these are common hazards.

Table 5.7 Scoring Matrix – Ecological Health Endpoints[1]

Hazard Endpoint	Classification	Concentration in Product			
		<10%	10-29%	30-59%	60-100%
Acute Aquatic Toxicity	Category 1	25	50	75	100
	Category 2	10	25	50	75
	Category 3	5	10	25	50
	Data Gap	10	25	50	75
Chronic Aquatic Toxicity[2]	Category 1	25	50	75	100
	Category 2	10	25	50	75
	Category 3	5	10	25	50
	Data Gap	10	25	50	75
Terrestrial Toxicity[3]	Yes/No	25	50	75	100
	Data Gap	0	0	0	0
Bioaccumulative	Yes/No	50	50	50	50
	Data Gap	25	25	25	25
Persistent	Persistent	50	50	50	50
	Inherently Biodegradable	10	10	10	10
	Readily Biodegradable	0	0	0	0
	Data Gap	25	25	25	25
Not Required to Be Classified		0	0	0	0

Notes:

AA = Alternatives Assessment; CSI = Chemical Scoring Index; SCP = Safer Consumer Products.

(1) The original CSI approach did not evaluate products if "more than 30% of [the] product's composition is due to the contribution of components with 'No Data Available,'" with the idea that the product will be re-evaluated at a later time "when more information may be available" (Verslycke *et al*., 2014). We did not follow this approach, because the SCP regulations do not require additional testing, and the timeframe for compliance would not allow for this. Additionally, the original CSI approach does not penalize data gaps on an *endpoint by endpoint* basis. This approach only penalizes a product if <30% of its composition is accounted for by components with data gaps (although the number of data gaps is immaterial), with a singular maximum penalty score of 100 for the environmental categories, 100 for the human health categories, and 50 for the physical categories. If chemicals with data gaps account for ≥30% of a product's composition, the product would be classified as "Do Not Evaluate." Thus, the CSI approach lacks granularity in terms of how many or which health endpoints have missing data. For this Abridged AA, we added endpoint by endpoint penalty scores for data gaps, which is more conservative than the CSI approach. The data gap penalty scores are lower than the Category 1 hazard scores for the same endpoint, and the data gap penalty scores generally decrease with decreasing chemical concentrations, except for certain endpoints of particular concern (*i.e.*, persistent and bioaccumulative).

(2) The CSI does not have scores for chronic aquatic toxicity. Thus, the CSI's scores for acute aquatic toxicity were used.

(3) The CSI does not have scores for terrestrial toxicity. Thus, we created scores for this endpoint. However, because many chemicals lack data for this endpoint, the data gap penalty score was zero.

Table 5.8 Scoring Matrix – Physical/Chemical Hazards[1]

Hazard Endpoint	Classification	Concentration in Product			
		<10%	10-29%	30-59%	60-100%
Ozone Depletion Potential	Yes	50	50	50	50
Direct Global Warming Contributor	Yes	10	25	50	75
Flammability (Liquid or Solid)	Category 1	25	50	75	100
	Category 2	10	25	50	75
	Category 3	5	10	25	50
VOC Contributing to Tropospheric Ozone Formation[2]	Yes	10	25	50	75
	Data Gap	5	10	25	25
"No" or Data Gap for Any Category Besides VOC		0	0	0	0

Notes:

AA = Alternatives Assessment; CSI = Chemical Scoring Index; SCP = Safer Consumer Products; VOC = Volatile Organic Compound.

(1) The original CSI approach did not evaluate products if "more than 30% of [the] product's composition is due to the contribution of components with 'No Data Available,'" with the idea that the product will be re-evaluated at a later time "when more information may be available" (Verslycke *et al*., 2014). We did not follow this approach, because the SCP regulations do not require additional testing, and the timeframe for compliance would not allow for this. Additionally, the original CSI approach does not penalize data gaps on an *endpoint by endpoint* basis. This approach only penalizes a product if <30% of its composition is accounted for by components with data gaps (although the number of data gaps is immaterial), with a singular maximum penalty score of 100 for the environmental categories, 100 for the human health categories, and 50 for the physical categories. If chemicals with data gaps account for ≥30% of a product's composition, the product would be classified as "Do Not Evaluate." Thus, the CSI approach lacks granularity in terms of how many or which health endpoints have missing data. For this Abridged AA, we added endpoint by endpoint penalty scores for data gaps, which is more conservative than the CSI approach. The data gap penalty scores are lower than the data-supported hazard scores for the same endpoint, and data gap penalty scores generally decrease with decreasing chemical concentrations.

(2) For this endpoint, we used a maximum score of 75 instead of the original maximum score of 50 in the CSI. Because VOCs' contribution to ozone formation is an important hazard for products, such as spray foam insulation, that are used in urban areas, and because smog formation is a particular concern for California cities, we increased the maximum score for this endpoint.

Table 5.9 Functional Ingredient-specific Hazard Scoring Summary

Priority Product and Alternative Formulations	Group	Human Health Score	Environmental Score	Physical Score	Total Score
Priority Product[1]					
Generic Formula for Group 1 (Low Pressure, Various Densities)	1	385-510	70-170	55-65	510-745
Generic Formula for Group 2 (High Pressure, Open Cell, 0.5 lb/ft^3)	2	255-380	0-100	50-60	305-540
Generic Formula for Group 3 (High Pressure, Medium Density, Closed Cell, 2 lbs/ft^3)	3	555	150	70	775
Non-MDI-based Alternative Formulations					
Firestone/Gaco Canary™ Example Formulation	Group 3 or 4	445	220	45	710
Hybrid Coatings Technologies/Nanotech Industries Green Polyurethane™ Example Formulation	Group 3 and/or 4; Not enough information to definitively assign grouping	575	325	10	910
Owens Corning Example Formulation	Group 2, 3, and/or 4; Not enough information to definitively assign grouping	755	470	10	1235
DuPont Patent No. WO 2013/101682 A1 Example Formulation	Group 2, 3, and/or 4; Not enough information to definitively assign grouping	375	195	0	570
Dow Patent No. WO 2015/142564 A1 Example Formulation	Group 2, 3, and/or 4; Not enough information to definitively assign grouping	435	175	25	635
DuPont Patent No. WO 2018/005142 A1 Example Formulation	Group 2, 3, and/or 4; Not enough information to definitively assign grouping	435	175	25	635
Lower-Exposure Approaches (Also Priority Products)					
Firestone/Gaco Profill System™	Group 2	255	0	50	305
High-Volume Low-Pressure (HVLP) Systems (*e.g.* , Nitrosys/ICP HandiFoam HVLP MD 2.0)	Group 3	520	120	65	705
BASF Patent No. 9592516 B2 Example Formulation	Groups 2 or 3	400	100	60	560
BASF Patent No. WO 2019/089237 A1 Example Formulation	Not enough information	655	295	75	1025

Notes:

MDI = Methylene Diphenyl Diisocyanate; SPF = Spray Polyurethane Foam.

(1) No generic formulation exists for Group 4: High Pressure, Closed Cell, 3 lbs/ft^3.

Table 5.10 Comparison of Product-level Performance

Priority Product and Potential Alternatives	Group	Core Density	Thermal Performance: R-Value	Tensile Strength ($lb_f/inch^2$, Same as psi)	Dimensional Stability (% Change in Volume)	Compressive Strength ($lb_f/inch^2$, Same as psi)	Adhesion ($lb_f/inch^2$, Same as psi)	Surface Burning Characteristics	Meet AC 377 Criteria?	Third-Party Certified as Compliant with the Following Codes	Sources
Criteria According to AC 377											
Sealing (nominal core density: 0.5-2.5 lbs/ft^3)	Group 1	As reported	Not required by AC 377; No minimum R value in CA JA4	Not required by AC 377	Not required by AC 377	Not required by AC 377	5 $lb_f/inch^2$, minimum	75 or lower flame-spread index; 450 or lower smoke-developed index	N/A	N/A	ICC-ES (2018, Table 1)
Low-Density Insulation (nominal core density: 0.5-1.4 lbs/ft^3)	Group 2	As reported	"As reported" (AC 377); 3.6/inch, minimum (CA JA4)	■ Minimum Closed Cell Content of 90%: 5 $lb_f/inch^2$, minimum ■ Closed Cell Content Less than 90%: 3 $lb_f/inch^2$, minimum	15% maximum total change	Not required by AC 377	Not required by AC 377	75 or lower flame-spread index; 450 or lower smoke-developed index	N/A	N/A	ICC-ES (2018, Table 1); California Energy Commission (2018b)
Medium-Density Insulation (nominal core density: 1.5-3.5 lbs/ft^3)	Group 3	As reported	"As reported" (AC 377); 5.8/inch, minimum (CA JA4)	15 $lb_f/inch^2$, minimum	15% maximum total change	15 $lb_f/inch^2$, minimum	Not required by AC 377	75 or lower flame-spread index; 450 or lower smoke-developed index	N/A	N/A	ICC-ES (2018, Table 1); California Energy Commission (2018b)
Roofing (nominal core density: 2.5-3.5 lbs/ft^3)	Group 4	As reported	"As reported" (AC 377); 5.8/inch, minimum (CA JA4)	40 $lb_f/inch^2$, minimum	15% maximum total change	40 $lb_f/inch^2$, minimum	Not required by AC 377	75 or lower flame-spread index	N/A	N/A	ICC-ES (2018, Table 1); California Energy Commission (2018b)
Priority Product											
Low Pressure (Various Densities) (*e.g.*, Dap Touch n' Seal 1.75 PCF ICC Closed Cell Polyurethane Foam Sealant)	Group 1	Example product: 1.75 lbs/ft^3	Generic: Not available; Example product: 6.2/inch (reported as 6.2 at 1 inch and 12.4 at 2 inches)	Example product: 31 psi	Not required by AC 377	Example product: 31 psi	20 psi (*via* communications with Dap)	Example product: 15 flame-spread index; 350 smoke-developed index	Yes	Example product (ICC-ES, 2020a): ■ 2018, 2015, 2012, and 2009 IBC ■ 2018, 2015, 2012, and 2009 IRC ■ 2018, 2015, 2012, and 2009 IECC ■ 2013 ADIBC	DAP Products Inc. (2019); ICC-ES (2020a)
High Pressure, Open Cell, 0.5 lb/ft^3 (*e.g.*, Accella Polyurethane Systems FOAMSULATE™ 50 HY)	Group 2	Example product: 0.5 lbs/ft^3	Generic: ~3.6-4.5/inch Example product: 3.7/inch (reported as 3.7 at 1 inch; 13 at 3.5 inches)	Example product: >3.0 psi	Example product: <15%	Not required by AC 377	Not required by AC 377	Example product: <25 flame-spread index; <450 smoke-developed index (ASTM E84)	Yes	Example Product (IAPMO, 2018): ■ 2015, 2012, 2009, and 2006 IBC ■ 2015, 2012, 2009, and 2006 IRC ■ 2015, 2012, 2009, and 2006 IECC	Carlisle Spray Foam Insulation (2019); ACC and SFC (2012); IAPMO (2018)
High Pressure, Medium Density, Closed Cell, 2 lbs/ft^3 (*e.g.*, Johns Manville Corbond III® SPF)	Group 3	Example product: 2.0 lbs/ft^3	Generic: ~5.8-6.8/inch Example product: 7/inch	Example product: 45 psi	Example product: 12% (158°F at 97% RH)	Example product: 36 psi	Not required by AC 377	Example product: <25 flame-spread Index; <450 smoke-developed index (ASTM E84)	Yes	Example Product (IAPMO, 2019): ■ 2015, 2012, and 2009 IBC ■ 2015, 2012, and 2009 IRC ■ 2015, 2012, and 2009 IECC ■ 2015, 2012, and 2009 NFPA 5000 Building Construction and Safety Code™	John Manville Inc. (2018); ACC and SFC (2012); IAPMO (2019)
High Pressure, Roofing, Closed Cell, 3 lbs/ft^3 (*e.g.*, SWD Urethane Quik-Shield 125)	Group 4	Example product: 3.0 lbs/ft^3	Generic: ~5.8-6.8/inch Example product: 6.3/inch (reported as 6.3 at 1 inch)	Example product: 70 psi	Example product: 3%	Example product: 60 psi	Not required by AC 377	Example product: <25 (2.7 density) and <75 (3 density) flame-spread Index	Yes	Example product (ICC-ES, 2020b): ■ 2018, 2015, 2012, 2009, and 2006 IBC ■ 2018, 2015, 2012, 2009, and 2006 IRC	SWD Urethane (2020); ACC and SFC (2012); ICC-ES (2020b)
Non-MDI-based Alternative Formulations											
Firestone/Gaco Canary™	Group 3 or 4	"The foam compositions may have a foam density of 0.1 lb/ft^3 to 30 lb/ft^3, 0.5 lb/ft^3 to 10 lb/ft^3, 1.5 lb/ft^3 to 10 lb/ft^3, 1.7 lb/ft^3 to 3.5 lb/ft^3, 1.5 lb/ft^3 to 2.5 lb/ft^3, or 1.7 lb/ft^3 to 2.5 lb/ft^3" (Trumbo *et al.*, 2016, p. 15)	Did not achieve according to communications with Firestone/Gaco (value not reported)	DG; Testing not performed. Development remains in progress according to communications with Firestone/Gaco	DG; Testing not performed. Development remains in progress according to communications with Firestone/Gaco	DG; Testing not performed. Development remains in progress according to communications with Firestone/Gaco	Not required by AC 377	Did not achieve, according to communications with Firestone/Gaco (value not reported)	No (did not achieve certain criteria and no data available for other criteria)	DG	Trumbo *et al.* (2016)
Hybrid Coatings Technologies/ Nanotech Industries Green Polyurethane™	Group 3 and/or 4; Not enough information	1.5 to 2.5 lbs/ft^3 (converted from 25 to 40 kg/m^3) (Figovsky *et al.*, 2015, p. 9)	3 to 4.7 (Figovsky *et al.*, 2015, p. 9)	DG	DG	29 to 58 psi (converted from 0.2 to 0.4 MPa) (Figovsky *et al.*, 2015, p. 9)	Not required by AC 377	DG. "Validated fire resistance" reported in NanoSonic Inc. (2012, p. 1)	No (did not achieve certain criteria, no validated test result available and no data available for other criteria)	DG	NanoSonic Inc. (2012); Figovsky *et al.* (2015)
Owens Corning	Group 2, 3, and/or 4; Not enough information	DG	"May be… about 3.0 to about 7.0 per inch" (Olang, 2012, p. 12)	DG	DG	DG	Not required by AC 377	DG	No (no validated test results available and no data available for other criteria)	DG	Olang (2012)
DuPont Patent No. WO 2013/101682 A1	Group 2, 3, and/or 4; Not enough information	Tested 10 examples densities ranged from 1.8 to 3 lbs/ft^3 (converted from 28.8 to 47.9 kg/m^3) (Jin *et al.*, 2013, pp. 22-23)	DG. Unable to test due to lack of working catalyst according to communications with DuPont.	DG. Unable to test due to lack of working catalyst according to communications with DuPont.	Achieved, according to communications with DuPont (value not reported)	Many examples tested, ranged from 20-28 psi (converted from 138-193 kPa) (Jin *et al.*, 2013, p. 22)	Not required by AC 377	3 examples, ASTM E84: 10 to <25 flame-spread index; 195 smoke-development index; <450 (12.7 mm panels), >450 (25.4 mm panels) smoke-development index (Jin *et al.*, 2013, p. 28)	No (did not achieve certain criteria and no data available for other criteria)	DG	Jin *et al.* (2013)

Priority Product and Potential Alternatives	Group	Core Density	Thermal Performance: R-Value	Tensile Strength ($lb_f/inch^2$, Same as psi)	Dimensional Stability (% Change in Volume)	Compressive Strength ($lb_f/inch^2$, Same as psi)	Adhesion ($lb_f/inch^2$, Same as psi)	Surface Burning Characteristics	Meet AC 377 Criteria?	Third-Party Certified as Compliant with the Following Codes	Sources
Dow Patent No. WO 2015/142564 A1	Group 2, 3, and/or 4; Not enough information	Example: 8.24 lbs/ft^3 (converted from 132 kg/m^3) (Foley *et al.* , 2015, p. 8)	DG	DG	DG	Example: 4.06 psi (converted from 28 kPa) (Foley *et al.* , 2015, p. 8)	Not required by AC 377	DG	No (did not achieve certain criteria and no data available for other criteria)	DG	Foley *et al.* (2015)
DuPont Patent No. WO 2018/005142 A1	Group 2, 3, and/or 4; Not enough information	Range of tested examples: 4.77 to 11.86 lbs/ft^3 (converted from 76.4 to 190 kg/m^3) (Thomas *et al.* , 2018, p. 19)	DG. Unable to test due to hydrolytic instability according to communications with DuPont.	DG. Unable to test due to hydrolytic instability according to communications with DuPont.	DG. However, examples are not hydrolytically stable (degrades in the presence of heat and moisture) according to communications with DuPont.	DG. Unable to test due to hydrolytic instability according to communications with DuPont.	Not required by AC 377	DG. Unable to test due to hydrolytic instability.	No (did not achieve certain criteria and no data available for other criteria)	DG	Thomas *et al.* (2018)
Lower-Exposure Approaches (Also Priority Products)											
Firestone/Gaco Profill System™ (FR6500R)	Group 2	0.55 lbs/ft^3 ± 10%	4.04 at 1 inch; 15.5 at 3.93 inches; 13.8 at 3.5 inches	3.1 psi	6% (7 days) maximum linear change	Not required by AC 377	Not required by AC 377	25 flame-spread index; 400 smoke-developed index	Yes	Intertek (2018): ■ 2018, 2015, and 2012 IBC ■ 2018, 2015, 2012, and 2009 IRC ■ 2018, 2015, 2012, and 2009 IECC	Gaco Western (2016); Intertek (2018)
High-Volume Low-Pressure (HVLP) Systems (*e.g.* , Nitrosys/ICP HandiFoam HVLP MD 2.0)	Group 3	2.0-2.3 lbs/ft^3	6.7/inch at >4-inch thickness; 6.9/inch at >4-inch thickness	62.4 $lb_f/inch^2$, Type C	4.9% (158°F [70°C]/97% RH [Relative Humidity]/168 hours)	26 lb_f/in^2, Parallel	Not required by AC 377	<25 flame-spread index; <450 smoke-developed index (tested at 4-inch thickness)	Yes	ICC-ES (2019): ■ 2015, 2012, and 2009 IBC ■ 2015, 2012, and 2009 IRC ■ 2015, 2012, and 2009 IECC ■ 2013 ADIBC ■ Other Codes: 2006 and 2003 IBC, IRC, and IECC	ICP Building Solutions Group (2019c); ICC-ES (2019)
BASF Patent No. 9592516 B2	Groups 2 or 3	DG	DG	DG. "[A] ratio of compressive strength to tensile strength of 0.5: 1 or greater and an elongation of 10 percent or less" (Wishneski *et al.* , 2017, p. 15)	No values provided. "These polyurethane foams also resist excessive creep and exhibit improved dimensional stability as compared to their counterparts" (Wishneski *et al.* , 2017, p. 13).	DG. "[A] ratio of compressive strength to tensile strength of 0.5: 1 or greater and an elongation of 10 percent or less" (Wishneski *et al.* , 2017, p. 15)	DG. "[M]ay contain... adhesion promoters" (Wishneski *et al.* , 2017, p. 18)	DG	No (no validated test results available and no data available for other criteria)	DG	Wishneski *et al.* (2017)
BASF Patent No. WO 2019/089237 A1	Not enough information	DG	DG	DG	DG	DG	DG	DG	No (no data available)	DG	Wishneski *et al.* (2019)

Notes:

ADIBC = Abu Dhabi International Building Code; DG = Data Gap; IBC = International Building Code; IECC = International Energy Conservation Code; IRC = International Residential Code; $lb_f/inch^2$ = Pound Force Per Square Inch; N/A = Not Applicable; NFPA = National Fire Protection Association; PPE = Personal Protective Equipment; psi = Pounds Per Square Inch; RE = Responsible Entity.

Performance data for the generic formula Priority Products are not available; thus, we selected a singular product and its performance data to represent each group. REs were selected to ensure a wide representation of companies in this table. Products were selected based on publicly available technical data sheets and third-party certifications.

CA JA4: California Energy Commission (2018b).

AC 377: ICC-ES (2018).

Table 5.11 Comparison of Product-level Functional Ingredient Emission

Priority Product and Potential Alternatives	Group	Emission Measurement for Functional Ingredient (*i.e.* , 4.4'-MDI [CAS No. 101-68-8] [ppm])[1]				Sources
		After SPF Application	Notes	During SPF Application	Notes	
Priority Products[2]						
Generic Formula: Low Pressure (Various Densities)	Group 1	At applicator: Not available Stationary sample: Not detected at 30 minutes after application	Measurement was taken 30 minutes after SPF application with ventilation (10.4 ACH). With ventilation is the industry workplace standard. Average detection limit ranged from 0.000153 ppm (<0.000153) to 0.000165 ppm (<0.000165).	At applicator: 0.0016 ppm average Stationary sample 2 ft behind applicator: 0.0007 ppm average (Note: One value was non-detect; thus, the detection limit was used for the average.)	Measurement was taken during SPF application (from 24 to 30 minutes) with ventilation (10.4 ACH). With ventilation is the industry workplace standard.	Wood (2017)
Generic Formula: High Pressure, Open Cell, 0.5 lb/ft^3	Group 2			At applicator: 0.0153 ppm average Stationary sample 2 ft behind applicator: 0.0077 ppm average	Measurement was taken during SPF application (from 20 to 23 minutes) with ventilation (10.4 ACH). With ventilation is the industry workplace standard.	Wood (2017)
Generic Formula: High Pressure, Medium Density, Closed Cell, 2 lbs/ft^3	Group 3			At applicator: 0.0268 ppm average Stationary sample 2 ft behind applicator: 0.0258 ppm average	Measurement was taken during SPF application (from 13 to 24 minutes) with ventilation (10.4 ACH). With ventilation is the industry workplace standard.	Wood (2017)
Generic Formula: High Pressure, Roofing, Closed Cell, 3 lbs/ft^3	Group 4	Not available (Note: Spray application of Group 4 products requires PPE and occurs outdoors; thus, exposure is limited.)	N/A	Not available (Note: Spray application of Group 4 products requires PPE and occurs outdoors; thus, exposure is limited.)	N/A	Wood (2017)
Non-MDI-based Alternative Formulations						
Firestone/Gaco Canary™	Group 3 or 4	DG (does not contain MDI/no test data)	N/A	DG (does not contain MDI/no test data)	N/A	Trumbo *et al.* (2016)
Hybrid Coatings Technologies/Nanotech Industries Green Polyurethane™	Group 3 and/or 4; Not enough information to assign definitively	DG (does not contain MDI/no test data)	N/A	DG (does not contain MDI/no test data)	N/A	NanoSonic Inc. (2012)
Owens Corning	Group 2, 3, and/or 4; Not enough information to assign definitively	DG (does not contain MDI/no test data)	N/A	DG (does not contain MDI/no test data)	N/A	Olang (2012)
DuPont Patent No. WO 2013/101682 A1	Group 2, 3, and/or 4; Not enough information to assign definitively	DG (does not contain MDI/no test data)	N/A	DG (does not contain MDI/no test data)	N/A	Jin *et al.* (2013)
Dow Patent No. WO 2015/142564 A1	Group 2, 3, and/or 4; Not enough information to assign definitively	DG (does not contain MDI/no test data)	N/A	DG (does not contain MDI/no test data)	N/A	Foley *et al.* (2015)
DuPont Patent No. WO 2018/005142 A1	Group 2, 3, and/or 4; Not enough information to assign definitively	DG (does not contain MDI/no test data)	N/A	DG (does not contain MDI/no test data)	N/A	Thomas *et al.* (2018)
Lower-Exposure Approaches (Also Priority Products)						
Firestone/Gaco Profill System™	Group 2	DG	N/A	0.0076 (ProFilm) 0.0010 (ProWeb) 0.3 (Generic comparable Group 2 SPF)	Measurement was taken during SPF application and without ventilation (*i.e.* , no fans and closed windows).	Nelson (2015)
High-Volume Low-Pressure (HVLP) Systems (*e.g.,* Nitrosys/ICP HandiFoam HVLP MD 2.0)	Group 3	Not detected at 1 hour after application.	Measurements were taken with ventilation (20 ACH). Detection limit not available.	DG	N/A	ICP Building Solutions Group (c. 2020)
BASF Patent No. 9592516 B2	Group 2 or 3	DG	N/A	2.5 ft from the cardboard test surface: 0.0233 (*vs* . 0.059 for the generic application system) 10 ft from the cardboard test surface: 0.00417 (*vs* . 0.007 for a generic application system)	Measurement was taken during SPF application (15 minutes). Ventilation status not reported.	Wishneski *et al.* (2017)
BASF Patent No. WO 2019/089237 A1	Not enough information	DG	N/A	On applicator: 0.012 average (10 ACH) and 0.014 average (20 ACH) 3 ft behind applicator: 0.0033 average (10 ACH) and 0.0041 average (20 ACH)	Measurement was taken during SPF application (15 minutes) with ventilation (*i.e.* , 10 and 20 ACH).	Wishneski *et al.* (2019)

Notes:

2,4-MDI = 2,4-Methylene Diphenyl Diisocyanate; 4,4'-MDI = 4,4'-Methylene Diphenyl Diisocyanate; ACGIH TLV = American Conference of Governmental Industrial Hygenists Threshold Limit Value; ACH = Air Changes Per Hour; CAS No. = Chemical Abstracts Service Registration Number; DG = Data Gap; MDI = Methylene Diphenyl Diisocyanate; N/A = Not Applicable; PPE = Personal Protective Equipment; ppm = Parts Per Million; SPF = Spray Polyurethane Foam.

(1) No emission data were available for the polyols.

(2) Wood (2017) reported MDI emission for the generic Priority Products with active ventilation of 10.4, 233, and 598 ACH during and after SPF application. Active ventilation is the industry workplace standard for SPF application, though Wood (2017) noted that ACHs of 233 and 598, while achievable in the laboratory setting, are not realistic or likely feasible on a construction site. Based on the technical infeasibility of achieving 233 and 598 ACH on a work jobsite, this table only summarizes the MDI emission from 10.4 ACH in this study for comparison purposes. Lastly, in addition to emissions for 4,4-MDI (CAS No. 101-68-8), Wood (2017) also reported emissions for 2,4-MDI (CAS No. 5873-54-1) and pMDI (CAS No. 9016-87-9). Since emission for 2,4-MDI is considerably lower than that of 4,4-MDI and because the other product emission studies in this section only reported 4,4-MDI emissions, we only summarized 4.4-MDI emission in Table 5.11 from Wood (2017). We also did not include emission of pMDI in this table because pMDI is not measured in the other emission studies. In addition, regulatory values for MDI, such as the ACGIH TLV, are based on 4,4-MDI (CAS No. 101-68-8).

Table 5.12 Ingredient-specific Physical-Chemical Properties

Priority Product and Potential Alternatives	Functional Ingredients	Percentage of Product (A- and B-Sides Combined)	SMILES	Molecular Weight	Density (g/cm^3)	Log K_{ow} (Octanol-Water Partition Coefficient, Describes Lipid Solubility)	Log K_{oa} (Octanol-Air Partition Coefficient)	Log K_{oc} (Organic Carbon Partition Coefficient, Describes Sorption in Soil and Sediment)	K_H[1] (Henry's Law Constant at 25°C, atm-m^3/mole)	Vapor Pressure (Saturated, mm Hg at 25°C)	Melting Point (°C at 1 atm)	Boiling Point[2] (°C at 1 atm)	Water Solubility (mg/L at 25 °C)	Physical State	Hydrolysis Rate Constant ($M^{-1}s^{-1}$)	Dissociation Constant
Priority Product																
pMDI/MDI in Priority Product	Unreacted MDI (CAS Nos. 101-68-8 and 26447-40-5) and pMDI (CAS No. 9016-87-9)	46.25-50	c1cc(ccc1N=C=O)Cc1ccc(cc1)N=C=O	250.252	1.2	**4.5**	8.94	3.9	2.30E-04	2.10E-05	42.00	>300 (decomposes)	**0.03**	Solid (MDI); Liquid (pMDI)	0.00061	Not applicable. MDI has no ionizable functional groups.
Polyester Polyol (in Low-Pressure and High-Pressure, Medium-Density Priority Products)	Polymer in Polyester Polyol (TSCA-exempted polymer, CAS No. may not have been assigned, 70%)	11.5-18.2	Unable to identify SMILES from chemical name	Unable to assess due to generic name and lack of CAS No.												
	Diethylene Glycol in Polyester Polyol (CAS No. 111-46-6, 30%)		O(CCO)CCO	106.12	**1.118**	-1.474	5.611	-1.1278	7.96E-10	**5.70E-03**	**-6.5**	**244.9**	**1.00E+06**	**Liquid**	DG	Does not have ionic structure
Polyether Polyol (in Low-Pressure and High-pressure, Low-Density Priority Products)	**Option A:** Polyether Polyol (*e.g.*, oxirane, 2-methyl-, polymer with oxirane, ether with 1,2,3-propanetriol [3:1] [CAS No. 9082-00-2])	11.5	Unable to identify SMILES for polymer[3]	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG
	Option B: Polyether Polyol (*e.g.*, sucrose, propylene oxide [CAS No. 9049-71-2])	11.5	Unable to identify SMILES for UVCB/polymer	440-720	1.12	-3.25	DG	**<1.25**	DG	**2.60E-04**	**No melting point observed**	**245 (decomposes)**	240,000.00	**Liquid**	DG	≥12.8 value ≤14.8
Aromatic Amino Polyether Polyol (in High-Pressure, Medium-Density Priority Products)	Oxirane, 2-Methyl-, Polymer with Oxirane, Ether with 2,6-bis((bis(2-Hydroxyethyl) amino)methyl)-4-branched Nonylphenol [CAS No. 940912-28-7])	16.81	Unable to identify SMILES for polymer	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG
Non-MDI-based Alternative Formulations																
Firestone/Gaco Canary™ Example Formulation	Sucrose Acetoacetate (No CAS No. identified)	26.09	Unable to identify SMILES from chemical name	Unable to assess due to generic name and lack of CAS No.												
	Glycerine Acetoacetate (No CAS No. identified)	26.09	Unable to identify SMILES from chemical name	Unable to assess due to generic name and lack of CAS No.												
	Meta Xylene Diamine (MXDA) (CAS No. 1477-55-0)	15.48	NCc(cccc1CN)c1	136.2	**1.05**	**0.18**	8.727	2.7098	9.28E-09	**5.18E-03**	**14**	**272**	**1.00E+05**	**Liquid**	DG	**9.52** and **8.30**
	Dytek® A (2-Methyl-1,5-diaminopentane) (CAS No. 15520-10-2)	10.26	NCC(CCCN)C	116.21	**0.865**	**≤1**	7.152	2.1595	8.48E-10	**0.196** at 20°C	**> -75 value < -20**	**192**	**>900,000** at 23.4°C	**Liquid**	DG	**10.6**
Hybrid Coatings Technologies/ Nanotech Industries Green Polyurethane™ Example Formulation	DER 331, Bisphenol-A Epoxy Resin (CAS No. 25085-99-8)	81.80	Unable to identify SMILES for polymer	DG	DG	DG	DG	DG	DG	**3.45E-10**	DG	DG	DG	**Liquid**	DG	DG
	Ancamine 2678 (No CAS No. identified)	14.30	Unable to identify SMILES from chemical name	Unable to assess due to generic name and lack of CAS No.												

Priority Product and Potential Alternatives	Functional Ingredients	Percentage of Product (A- and B-Sides Combined)	SMILES	Molecular Weight	Density (g/cm^3)	Log K_{ow} (Octanol-Water Partition Coefficient, Describes Lipid Solubility)	Log K_{oa} (Octanol-Air Partition Coefficient)	Log K_{oc} (Organic Carbon Partition Coefficient, Describes Sorption in Soil and Sediment)	K_H[1] (Henry's Law Constant at 25°C, atm-m^3/mole)	Vapor Pressure (Saturated, mm Hg at 25°C)	Melting Point (°C at 1 atm)	Boiling Point[2] (°C at 1 atm)	Water Solubility (mg/L at 25 °C)	Physical State	Hydrolysis Rate Constant ($M^{-1}s^{-1}$)	Dissociation Constant
Owens Corning Example Formulation	DER 331, Bisphenol-A Epoxy Resin (CAS No. 25085-99-8)	45.73	Unable to identify SMILES for polymer	DG	DG	DG	DG	DG	DG	**3.45E-10**	DG	DG	DG	**Liquid**	DG	DG
	Epon™ 8111, Multifunctional Epoxy Resin (CAS No. 25068-38-6)	16.34	Unable to identify SMILES for polymer	DG	**1.16**	**3.242**	DG	DG	DG	6.72E-08	**-16**	**320**	**6.90E+00**	**Liquid**	DG	DG
	Epon™ 8111, Multifunctional Epoxy Resin (CAS No. 15625-89-5)		O=C(OCC(CC)(COC(=O)C=C)COC(=O)C=C)C=C	296.32	**1.11 at 20°C**	2.86	10.47	**2.2**	6.58E-12	**5.63E-04**	27.19	322.42	74.317	**Liquid**	DG (prediction unreliable due to lack of underlying data)	Not applicable, does not dissociate
	Cycloate A (CAS No. 1134-23-2)/ Ancamine 2678 (no CAS No. identified)	17.49	CAS No. 1134-23-2: CCSC(=O)N(CC)C1CCCCC1	215.36	**1.0156**	**3.88**	7.442	**2.538**	**6.70E-06**	**2.00E-03**	**11.5**	**145 (at 0.013 atm)**	**85**	**Liquid**	DG	DG
	Epikure™ 3271 (CAS No. 111-40-0)	4.08	N(CCN)CCN	103.17	**0.9586**	-2.1324	8.767	**≥3.4 value ≤4.6**	3.12E-08	**2.30E-01**	**-39**	**207**	**1.00E+06**	**Liquid**	DG	**4.83**, **9.39**, and **10.1**
	Epikure™ 3271 (CAS No. 80-05-7)		CC(C)(c1ccc(O)cc1)c2ccc(O)cc2	228.29	**1.2**	**3.4**	12.186	**2.89-3.93**	3.12E-12	**3.09E-09**	**155**	**360 (with decomposition)**	**298**	**Solid**	DG	**11.3**
DuPont Patent No. WO 2013/101682 A1 Example Formulation	Tetrafunctional Acrylate (CAS No. 94108-97-1)	30.04	O=C(OCC(COCC(COC(=O)C=C)(COC(=O)C=C)CC)(COC(=O)C=C)CC)C=C	466.53	1.08	4.34	16.167	5.291	9.96E-18	2.13E-08	148.97	454.15	1.0675	Solid	DG (prediction unreliable due to lack of underlying data)	DG
	Difunctional Acrylate A (CAS No. 55818-57-0)	10.94	Unable to identify SMILES because compound is an oligomer	DG	DG	DG	DG	**3.55**	DG	DG	DG	DG	DG	**Liquid**	DG	DG
	Trimethylolpropane tris(Acetoacetonate) (CAS No. 22208-25-9)	32.26	CCC(COC(=O)CC(=O)C)(COC(=O)CC(=O)C)COC(=O)CC(=O)C	386.4	1.19	-1.4038	14.892	M	1.25E-18	0.021 at 20°c	152.85	>253-300	>22,000 at 20°C	Liquid	DG (prediction unreliable due to lack of underlying data)	DG
Dow Patent No. WO 2015/142564 A1 Example Formulation	Polycarbamate (no CAS No., reaction product)	45.00	Unable to identify SMILES from chemical name	Unable to assess due to generic name and lack of CAS No.												
	1,3- and 1,4-Cyclohexane Dicarboxaldehyde (CHDA) (EC No. 482-020-3, no CAS No., assuming purified grade)		Unable to identify SMILES due to mixture	DG	**1.06**	**0.9**	DG	DG	DG	**0.0352 ± 0.003 at 20°C**	**No melting temperature ≥ -90°C**	>200 to <250	**166,000** at 20°C	Liquid	DG	Does not have any functional groups that dissociate
DuPont Patent No. WO 2018/005142 A1 Example Formulation	Polycarbamate 2 (no CAS No., reaction product)	~31.60	Unable to identify SMILES from chemical name	Unable to assess due to generic name and lack of CAS No.												
	1,3- and 1,4-Cyclohexane dicarboxaldehyde (CHDA) (EC No. 482-020-3, no CAS No., assuming purified grade)		Unable to identify SMILES due to mixture	DG	**1.06**	**0.9**	DG	DG	DG	**0.0352 ± 0.003 at 20°C**	**No melting temperature ≥ -90°C**	>200 to <250	**166,000** at 20°C	Liquid	DG	Does not have any functional groups that dissociate
Lower-Exposure Alternatives (Also Priority Products)																
Firestone/Gaco Profill System™	Unreacted MDI (CAS Nos. 101-68-8 and 26447-40-5) and pMDI (CAS No. 9016-87-9)	50.00	c1cc(ccc1N=C=O)Cc1ccc(cc1)N=C=O	250.252	1.2	**4.5**	8.94	3.9	2.30E-04	2.10E-05	42.00	>300 (decomposes)	**0.03**	Solid	0.00061	Not applicable. MDI has no ionizable functional groups.
	beta-D-Fructofuranosyl alpha-D-Glucopyranoside/Sucrose (CAS No. 57-50-1)	15.00	O(C(C(O)C(O)C1O)CO)C1OC(OC(C2O)CO)(C2O)CO	342.3	**1.581**	**-3.7**	16.038	0.9828	4.47E-22	0 (approximately)	**185.5**	591.59	**2.10E+06**	Solid	DG	**12.62**

Priority Product and Potential Alternatives	Functional Ingredients	Percentage of Product (A- and B-Sides Combined)	SMILES	Molecular Weight	Density (g/cm^3)	Log K_{ow} (Octanol-Water Partition Coefficient, Describes Lipid Solubility)	Log K_{oa} (Octanol-Air Partition Coefficient)	Log K_{oc} (Organic Carbon Partition Coefficient, Describes Sorption in Soil and Sediment)	K_H[1] (Henry's Law Constant at 25°C, atm-m^3/mole)	Vapor Pressure (Saturated, mm Hg at 25°C)	Melting Point (°C at 1 atm)	Boiling Point[2] (°C at 1 atm)	Water Solubility (mg/L at 25 °C)	Physical State	Hydrolysis Rate Constant (M^{-1}s^{-1})	Dissociation Constant
High-Volume Low-Pressure (HVLP) Systems (*e.g.,* Nitrosys/ICP HandiFoam HVLP MD 2.0)	Unreacted MDI (CAS Nos. 101-68-8 and 26447-40-5) and pMDI (CAS No. 9016-87-9)	50.00	c1cc(ccc1N=C=O)Cc1ccc(cc1)N=C=O	250.252	1.2	**4.5**	8.94	3.9	2.30E-04	2.10E-05	42.00	>300 (decomposes)	**0.03**	Solid	0.00061	Not applicable. MDI has no ionizable functional groups.
	Polymer in Polyester Polyol (TSCA-exempted polymer, CAS No. may not have been assigned)	~8 (based on generic formula)	Unable to identify SMILES from chemical name	Unable to assess due to generic name and lack of CAS No.												
	Diethylene Glycol (CAS No. 111-46-6)	2.50	O(CCO)CCO	106.12	**1.118**	-1.474	5.611	-1.1278	7.96E-10	**5.70E-03**	**-6.5**	**244.9**	**1.00E+06**	**Liquid**	DG	Does not have ionic structure
	Aromatic Amino Polyether Polyol: Oxirane, 2-Methyl-, Polymer with Oxirane, Ether with 2,6-bis((bis(2-Hydroxyethyl) amino)methyl)-4-branched Nonylphenol [CAS No. 940912-28-7])	16.81	Unable to identify SMILES for polymer	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG
BASF Patent No. 9592516 B2 Example Formulation	Unreacted MDI (CAS Nos. 101-68-8 and 26447-40-5) and pMDI (CAS No. 9016-87-9)	50.00	c1cc(ccc1N=C=O)Cc1ccc(cc1)N=C=O	250.252	1.2	**4.5**	8.94	3.9	2.30E-04	2.10E-05	42.00	>300 (decomposes)	**0.03**	Solid	0.00061	Not applicable. MDI has no ionizable functional groups.
	Diethylene Glycol (CAS No. 111-46-6)	22.50	O(CCO)CCO	106.12	**1.118**	-1.474	5.611	-1.1278	7.96E-10	**5.70E-03**	**-6.5**	**244.9**	**1.00E+06**	**Liquid**	DG	Does not have ionic structure
	Polyether Polyol (*e.g.* , oxirane, 2-methyl-, polymer with oxirane, ether with 1,2,3-propanetriol [3:1] [CAS No. 9082-00-2])	12.50	Unable to identify SMILES for polymer[3]	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG
	Polyether polyol (*e.g.* , sucrose, propylene oxide [CAS No. 9049-71-2])	5.00	Unable to identify SMILES for UVCB/polymer	440-720	1.12	-3.25	DG	**<1.25**	DG	**2.60E-04**	**No melting point observed**	**245 (decomposes)**	240,000.00	**Liquid**	DG	≥ 12.8 ≤ 14.8
BASF Patent No. WO 2019/089237 A1 Example Formulation	Unreacted MDI (CAS Nos. 101-68-8 and 26447-40-5) and pMDI (CAS No. 9016-87-9)	50.00	c1cc(ccc1N=C=O)Cc1ccc(cc1)N=C=O	250.252	1.2	**4.5**	8.94	3.9	2.30E-04	2.10E-05	42.00	>300 (decomposes)	**0.03**	Solid	0.00061	Not applicable. MDI has no ionizable functional groups.
	Aromatic Polyester (*e.g.* , Terol 258) (cannot identify CAS No.)	22.56	Unable to identify SMILES from chemical name	Unable to assess due to generic name and lack of CAS No.												
	GSP-280 Polyol (CAS No. 26301-10-0)	11.87	Unable to identify SMILES for polymer	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG
	GSP-280 Polyol (CAS No. 9082-00-2)		Unable to identify SMILES for polymer[3]	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG	DG

Notes:

CAS No. = Chemical Abstracts Service Registry Number; DG = Data Gap; MDI = Methylene Diphenyl Diisocyanate; pMDI = Polymeric Methylene Diphenyl Diisocyanate; OH = Hydroxyl Radical; RE = Responsible Entity; SMILES = Simplified Molecular-Input Line-Entry System; TSCA = Toxic Substances Control Act; US EPA = United States Environmental Protection Agency; UVCB = Unknown or Variable Composition, Complex Reaction Products and Biological Materials.

Bolded text indicates experimental values. Non-bolded text indicates modeled or calculated values. If available, experimental melting point, boiling point, vapor pressure, and water solubility values listed in the table were manually entered for more accurate modeling in US EPA's EPI Suite software (US EPA, 2019b).

Data were mainly obtained from ECHA (2020) and US EPA's EPI Suite software (US EPA, 2019b). Additional sources include Bratfisch *et al.* (2020), Carter *et al.* (1999), the Hazardous Substances Data Bank (HSDB) (NLM, 2005-2013), International Isocyanate Institute (1991), OECD (2002), Olf (2018), Plehiers *et al.* (2019), and US EPA's CompTox Chemicals Dashboard (US EPA, 2019c).

(1) Reference hierarchy of Henry's Law Constant sources in EPI Suite: (1) Vapor pressure/water solubility, if experimental data are available; (2) Group; (3) Bond.

(2) Boiling point: Preference was given to experimental value reported at 1 atm or 760 mm Hg. Otherwise, a modeled estimate from EPI Suite was used (US EPA, 2019b).

(3) While EPI Suite provides predicted values for this polymer when searching by CAS No., the values may not reflect the exact number of repeating monomers used by REs and the alternatives patent holders. Thus, no data are presented for this polymer.

Table 5.12 Ingredient-specific Physical-Chemical Properties

Priority Product and Potential Alternatives	Functional Ingredients	Percentage of Product (A- and B-Sides Combined)	Photolysis Rate Constant (s^{-1})	Standard Reduction Potential (V)	Air Diffusion Coefficient (Diffusivity) (cm^2/s)	Water Diffusion Coefficient (Diffusivity) (cm^2/s)	Reactivity/ Electrophilicity Index	Environmental Half-life in Air (Days)
Priority Product								
pMDI/MDI in Priority Product	Unreacted MDI (CAS Nos. 101-68-8 and 26447-40-5) and pMDI (CAS No. 9016-87-9)	46.25-50	0.000018 (estimated for indirect atmosphoric photolysis at 1.5E6 molecules OH/cm^3)	DG	Not applicable, ingredient is a solid	0.0000049	DG	0.93
Polyester Polyol (in Low-Pressure and High-Pressure, Medium-Density Priority Products)	Polymer in Polyester Polyol (TSCA-exempted polymer, CAS No. may not have been assigned, 70%)	11.5-18.2	Unable to assess due to generic name and lack of CAS No.					
	Diethylene Glycol in Polyester Polyol (CAS No. 111-46-6, 30%)		DG	DG	Not applicable, ingredient is a liquid	DG	DG	0.479
Polyether Polyol (in Low-Pressure and High-pressure, Low-Density Priority Products)	**Option A:** Polyether Polyol (*e.g.* , oxirane, 2-methyl-, polymer with oxirane, ether with 1,2,3-propanetriol [3:1] [CAS No. 9082-00-2])	11.5	DG	DG	DG	DG	DG	DG
	Option B: Polyether Polyol (*e.g.* , sucrose, propylene oxide [CAS No. 9049-71-2])	11.5	DG	DG	Not applicable, ingredient is a liquid	DG	DG	≥0.0625 value ≤0.12
Aromatic Amino Polyether Polyol (in High-Pressure, Medium-Density Priority Products)	Oxirane, 2-Methyl-, Polymer with Oxirane, Ether with 2,6-bis((bis(2-Hydroxyethyl) amino)methyl)-4-branched Nonylphenol [CAS No. 940912-28-7])	16.81	DG	DG	DG	DG	DG	DG
Non-MDI-based Alternative Formulations								
Firestone/Gaco Canary™ Example Formulation	Sucrose Acetoacetate (No CAS No. identified)	26.09	Unable to assess due to generic name and lack of CAS No.					
	Glycerine Acetoacetate (No CAS No. identified)	26.09	Unable to assess due to generic name and lack of CAS No.					
	Meta Xylene Diamine (MXDA) (CAS No. 1477-55-0)	15.48	DG	DG	Not applicable, ingredient is a liquid	DG	DG	0.15
	Dytek® A (2-Methyl-1,5-diaminopentane) (CAS No. 15520-10-2)	10.26	DG	DG	Not applicable, ingredient is a liquid	DG	DG	0.154
Hybrid Coatings Technologies/ Nanotech Industries Green Polyurethane™ Example Formulation	DER 331, Bisphenol-A Epoxy Resin (CAS No. 25085-99-8)	81.80	DG	DG	Not applicable, ingredient is a liquid	DG	DG	DG
	Ancamine 2678 (No CAS No. identified)	14.30	Unable to assess due to generic name and lack of CAS No.					

Priority Product and Potential Alternatives	Functional Ingredients	Percentage of Product (A- and B-Sides Combined)	Photolysis Rate Constant (s^{-1})	Standard Reduction Potential (V)	Air Diffusion Coefficient (Diffusivity) (cm^2/s)	Water Diffusion Coefficient (Diffusivity) (cm^2/s)	Reactivity/ Electrophilicity Index	Environmental Half-life in Air (Days)
Owens Corning Example Formulation	DER 331, Bisphenol-A Epoxy Resin (CAS No. 25085-99-8)	45.73	DG	DG	Not applicable, ingredient is a liquid	DG	DG	DG
	Epon™ 8111, Multifunctional Epoxy Resin (CAS No. 25068-38-6)	16.34	DG	DG	Not applicable, ingredient is a liquid	DG	DG	DG
	Epon™ 8111, Multifunctional Epoxy Resin (CAS No. 15625-89-5)		DG	DG	Not applicable, ingredient is a liquid	DG	DG	**0.311**
	Cycloate A (CAS No. 1134-23-2)/ Ancamine 2678 (no CAS No. identified)	17.49	DG	DG	Not applicable, ingredient is a liquid	DG	DG	0.27
	Epikure™ 3271 (CAS No. 111-40-0)	4.08	DG	DG	Not applicable, ingredient is a liquid	DG	DG	0.072
	Epikure™ 3271 (CAS No. 80-05-7)		DG	DG	Not applicable, ingredient is a solid	DG	DG	**0.133**
DuPont Patent No. WO 2013/101682 A1 Example Formulation	Tetrafunctional Acrylate (CAS No. 94108-97-1)	30.04	DG	DG	Not applicable, ingredient is a solid	DG	DG	**0.176**
	Difunctional Acrylate A (CAS No. 55818-57-0)	10.94	DG	DG	Not applicable, ingredient is a liquid	DG	DG	DG
	Trimethylolpropane tris(Acetoacetonate) (CAS No. 22208-25-9)	32.26	DG	DG	Not applicable, ingredient is a liquid	DG	DG	1.373
Dow Patent No. WO 2015/142564 A1 Example Formulation	Polycarbamate (no CAS No., reaction product)	45.00	Unable to assess due to generic name and lack of CAS No.					
	1,3- and 1,4-Cyclohexane Dicarboxaldehyde (CHDA) (EC No. 482-020-3, no CAS No., assuming purified grade)		DG	DG	Not applicable, ingredient is a liquid	DG	DG	0.2
DuPont Patent No. WO 2018/005142 A1 Example Formulation	Polycarbamate 2 (no CAS No., reaction product)	~31.60	Unable to assess due to generic name and lack of CAS No.					
	1,3- and 1,4-Cyclohexane dicarboxaldehyde (CHDA) (EC No. 482-020-3, no CAS No., assuming purified grade)		DG	DG	Not applicable, ingredient is a liquid	DG	DG	0.2
Lower-Exposure Alternatives (Also Priority Products)								
Firestone/Gaco Profill System™	Unreacted MDI (CAS Nos. 101-68-8 and 26447-40-5) and pMDI (CAS No. 9016-87-9)	50.00	0.000018 (estimated for indirect atmosphoric photolysis at 1.5E6 molecules OH/cm^3)	DG	Not applicable, ingredient is a solid	0.0000049	DG	0.93
	beta-D-Fructofuranosyl alpha-D-Glucopyranoside/Sucrose (CAS No. 57-50-1)	15.00	DG	DG	Not applicable, ingredient is a solid	DG	DG	0.093

Priority Product and Potential Alternatives	Functional Ingredients	Percentage of Product (A- and B-Sides Combined)	Photolysis Rate Constant (s^{-1})	Standard Reduction Potential (V)	Air Diffusion Coefficient (Diffusivity) (cm^2/s)	Water Diffusion Coefficient (Diffusivity) (cm^2/s)	Reactivity/ Electrophilicity Index	Environmental Half-life in Air (Days)
High-Volume Low-Pressure (HVLP) Systems (*e.g.*, Nitrosys/ICP HandiFoam HVLP MD 2.0)	Unreacted MDI (CAS Nos. 101-68-8 and 26447-40-5) and pMDI (CAS No. 9016-87-9)	50.00	0.000018 (estimated for indirect atmospheric photolysis at 1.5E6 molecules OH/cm^3)	DG	Not applicable, ingredient is a solid	0.0000049	DG	0.93
	Polymer in Polyester Polyol (TSCA-exempted polymer, CAS No. may not have been assigned)	~8 (based on generic formula)	Unable to assess due to generic name and lack of CAS No.					
	Diethylene Glycol (CAS No. 111-46-6)	2.50	DG	DG	Not applicable, ingredient is a liquid	DG	DG	0.479
	Aromatic Amino Polyether Polyol: Oxirane, 2-Methyl-, Polymer with Oxirane, Ether with 2,6-bis((bis(2-Hydroxyethyl) amino)methyl)-4-branched Nonylphenol [CAS No. 940912-28-7])	16.81	DG	DG	DG	DG	DG	DG
BASF Patent No. 9592516 B2 Example Formulation	Unreacted MDI (CAS Nos. 101-68-8 and 26447-40-5) and pMDI (CAS No. 9016-87-9)	50.00	0.000018 (estimated for indirect atmospheric photolysis at 1.5E6 molecules OH/cm^3)	DG	Not applicable, ingredient is a solid	0.0000049	DG	0.93
	Diethylene Glycol (CAS No. 111-46-6)	22.50	DG	DG	Not applicable, ingredient is a liquid	DG	DG	0.479
	Polyether Polyol (*e.g.* , oxirane, 2-methyl-, polymer with oxirane, ether with 1,2,3-propanetriol [3:1] [CAS No. 9082-00-2])	12.50	DG	DG	DG	DG	DG	DG
	Polyether polyol (*e.g.* , sucrose, propylene oxide [CAS No. 9049-71-2])	5.00	DG	DG	Not applicable, ingredient is a liquid	DG	DG	≥0.0625 value ≤0.12
BASF Patent No. WO 2019/089237 A1 Example Formulation	Unreacted MDI (CAS Nos. 101-68-8 and 26447-40-5) and pMDI (CAS No. 9016-87-9)	50.00	0.000018 (estimated for indirect atmospheric photolysis at 1.5E6 molecules OH/cm^3)	DG	Not applicable, ingredient is a solid	0.0000049	DG	0.93
	Aromatic Polyester (*e.g.* , Terol 258) (cannot identify CAS No.)	22.56	Unable to assess due to generic name and lack of CAS No.					
	GSP-280 Polyol (CAS No. 26301-10-0)	11.87	DG	DG	DG	DG	DG	DG
	GSP-280 Polyol (CAS No. 9082-00-2)		DG	DG	DG	DG	DG	DG

Notes:

CAS No. = Chemical Abstracts Service Registry Number; DG = Data Gap; MDI = Methylene Diphenyl Diisocyanate; pMDI = Polymeric Methylene Diphenyl Diisocyanate; OH = Hydroxyl Radical; RE = Responsible Entity; SMILES = Simplified Molecular-Input Line-Entry System; TSCA = Toxic Substances Control Act; US EPA = United States Environmental Protection Agency; UVCB = Unknown or Variable Composition, Complex Reaction Products and Biological Materials.

Bolded text indicates experimental values. Non-bolded text indicates modeled or calculated values. If available, experimental melting point, boiling point, vapor pressure, and water solubility values listed in the table were manually entered for more accurate modeling in US EPA's EPI Suite software (US EPA, 2019b).

Data were mainly obtained from ECHA (2020) and US EPA's EPI Suite software (US EPA, 2019b). Additional sources include Bratfisch *et al.* (2020), Carter *et al.* (1999), the Hazardous Substances Data Bank (HSDB) (NLM, 2005-2013), International Isocyanate Institute (1991), OECD (2002), Olf (2018), Plehiers *et al.* (2019), and US EPA's CompTox Chemicals Dashboard (US EPA, 2019c).

(1) Reference hierarchy of Henry's Law Constant sources in EPI Suite: (1) Vapor pressure/water solubility, if experimental data are available; (2) Group; (3) Bond.

(2) Boiling point: Preference was given to experimental value reported at 1 atm or 760 mm Hg. Otherwise, a modeled estimate from EPI Suite was used (US EPA, 2019b).

(3) While EPI Suite provides predicted values for this polymer when searching by CAS No., the values may not reflect the exact number of repeating monomers used by REs and the alternatives patent holders. Thus, no data are presented for this polymer.

Table 5.13 Abridged Alternatives Analysis Conclusions

Priority Product and Alternative Formulations	Group	Ingredient Hazard: Human Health Score	Ingredient Hazard: Environmental Score	Ingredient Hazard: Physical Score	Ingredient Hazard: Total Score	Product Performance: Meet AC 377 Criteria?	Product Emission for MDI	Ingredient Exposure Potential[1]	Relative Product Cost	Conclusions
Generic Formula Priority Products for Comparison										
Low Pressure (Various Densities)	1	385-510	70-170	55-65	510-745	Yes (*e.g.*, Touch n' Seal 1.75 PCF ICC Closed Cell Polyurethane Foam Sealant)	All with ventilation (10.4 ACH) – On applicator and during application: 0.0016 ppm average; 2 ft behind applicator and during application: 0.0007 ppm average; Not detected at 30 minutes after application	N/A (baseline for comparison)	N/A (baseline for comparison)	N/A (baseline for comparison)
High Pressure, Open Cell, 0.5 lb/ft^3	2	255-380	0-100	50-60	305-540	Yes (*e.g.*, Accella Polyurethane Systems FOAMSULATE™ 50 HY)	All with ventilation (10.4 ACH) – On applicator and during application: 0.0153 ppm average; 2 ft behind applicator and during application: 0.0077 ppm average; Not detected at 1 hour after application	N/A (baseline for comparison)	N/A (baseline for comparison)	N/A (baseline for comparison)
High Pressure, Medium Density, Closed Cell, 2 lbs/ft^3	3	555	150	70	775	Yes (*e.g.*, Johns Manville Corbond III® SPF)	All with ventilation (10.4 ACH) – On applicator and during application: 0.0268 ppm average; 2 ft behind applicator and during application: 0.0258 ppm average; Not detected at 1 hour after application	N/A (baseline for comparison)	N/A (baseline for comparison)	N/A (baseline for comparison)
High Pressure, Roofing, Closed Cell, 3 lbs/ft^3	4	Not available (no generic formula for Group 4 Priority Products)				Yes (*e.g.*, SWD Urethane Quik-Shield 125)	Not available	Not available	N/A (baseline for comparison)	N/A (baseline for comparison)
Non-MDI-based Alternative Formulations										
Firestone/Gaco Canary™ Example Formulation	Group 3 or 4	Lower (445)	Similar (220)	Lower (45)	Lower (710)	No (did not achieve R value and surface burning characteristics and no data available for other criteria)	N/A (does not contain MDI)	Higher exposure potential *via* air and water. Higher sorption potential to soil and sediment and lower exposure potential to groundwater *via* migration from soil/sediment.	No data available for comparison	Not a suitable alternative: Lower hazard score. Does not meet several performance criteria. Higher ingredient exposure potential. No cost information available. Does not replace all groups.
Hybrid Coatings Technologies/ Nanotech Industries Green Polyurethane™ Example Formulation	Group 3 and/or 4; Not enough information to definitively assign grouping.	Similar (575)	Higher (325)	Lower (10)	Higher (910)	No (did not achieve certain criteria, no validated test result available and no data available for other criteria)	N/A (does not contain MDI)	Lower exposure potential *via* air. No data available on water, soil, sediment, or groundwater (*via* migration from soil/sediment) exposure potential.	No data available for comparison	Not a suitable substitute: Higher hazard score. Does not meet a performance criterion and no data available for other criteria. Lower exposure potential *via* air. No cost information available. Does not replace all groups.
Owens Corning Example Formulation	Group 2, 3, and/or 4; Not enough information to definitively assign grouping.	Substantially higher (755)	Substantially higher (470)	Lower (10)	Substantially higher (1,235)	No (no validated test results available and no data available for other criteria)	N/A (does not contain MDI)	Some ingredients have higher while others have lower exposure potential *via* water. Lower exposure potential *via* air.	No data available for comparison	Not a suitable substitute: Substantially higher hazard score. Little information on performance. Varied ingredient exposure potential. No cost information available. Does not replace all groups.
DuPont Patent No. WO 2013/101682 A1 Example Formulation	Group 2, 3, and/or 4; Not enough information to definitively assign grouping.	Similar (375)	Similar (195)	Lower (0)	Similar (570)	No (did not achieve dimensional stability and no data available for other criteria)	N/A (does not contain MDI)	One ingredient has higher while another has lower exposure potential *via* air and water. Higher sorption potential to soil and sediment but lower exposure potential to groundwater *via* migration from soil/sediment.	No data available for comparison	Not a suitable substitute: Similar hazard score. Does not meet performance criteria. Varied ingredient exposure potential. No cost information available. Does not replace all groups.
Dow Patent No. WO 2015/142564 A1 Example Formulation	Group 2, 3, and/or 4; Not enough information to definitively assign grouping.	Similar (435)	Similar (175)	Lower (25)	Similar (635)	No (did not achieve compressive strength and no data available for other criteria)	N/A (does not contain MDI)	Higher exposure potential *via* air. Similar exposure potential *via* water. No data available on soil, sediment, or groundwater (*via* migration from soil/sediment) exposure potential.	No data available for comparison	Not a suitable substitute: Similar hazard score. Does not meet performance criteria. Higher ingredient exposure potential. No cost information available. Does not replace all groups.
DuPont Patent No. WO 2018/005142 A1 Example Formulation	Group 2, 3, and/or 4; Not enough information to definitively assign grouping.	Similar (435)	Similar (175)	Lower (25)	Similar (635)	No (hydrolytically unstable and no data available for other criteria)	N/A (does not contain MDI)	Higher exposure potential *via* air. Similar exposure potential *via* water. No data available on soil, sediment, or groundwater (*via* migration from soil/sediment) exposure potential.	No data available for comparison	Not a suitable substitute: Similar hazard score. Does not meet performance criteria. Higher ingredient exposure potential. No cost information. Does not replace all groups.
Lower-Exposure Approaches (Also Priority Products)										
Firestone/Gaco Profill System™	Group 2	Similar (255)	Similar (0)	Similar (50)	Similar (305)	Yes	Substantially lower than generic SPF during application and without ventilation. Note that use of appropriate ventilation is the industry workplace standard/requirement and PPE is still required for all Profill System products.	Higher exposure potential *via* water. Similar exposure potential exposure *via* air. Similar sorption potential to soil and sediment and similar exposure potential to groundwater *via* migration from soil/sediment.	Higher material costs for membranes and channels. Variable labor cost (higher for membrane/channel installation, but lower for decreased trimming), which may vary by operator.	Not a suitable substitute: Similar hazard score. Meets performance criteria. Lower MDI emission. Higher ingredient exposure potential based on ingredient physical-chemical properties. Variable cost for product use. Does not replace all groups.
High-Volume Low-Pressure (HVLP) Systems (*e.g.*, Nitrosys/ICP HandiFoam HVLP MD 2.0)	Group 3	Similar (520)	Similar (120)	Similar (65)	Similar (705)	Yes	Similar. Not detected at 1 hour after application with ventilation. No data are available for during application.	Similar exposure potential *via* air, water, soil, sediment, and groundwater *via* migration from soil/sediment.	Higher equipment cost for separate purchase of Nitrosys equipment. Similar labor cost.	Not a suitable substitute: Similar hazard score compared to Group 3 Priority Products. Meets performance criteria. Similar MDI emission. Similar ingredient exposure potential based on ingredient physical-chemical properties. Higher equipment cost. Does not replace all groups.
BASF Patent No. 9592516 B2 (example formulation)	Group 2 or 3	Similar (400)	Similar (100)	Similar (60)	Similar (560)	No (no validated test results available and no data available for other criteria)	Lower than generic SPF during application. Ventilation not reported. Patent describes the technology to "minimize a need to use respirators and protective equipment" (Wishneski *et al.*, 2017), but makes no claim as to whether PPE are needed or not.	Similar exposure potential *via* air, water, soil, sediment, and groundwater *via* migration from soil/sediment.	No data available for comparison	Not suitable substitute: Similar hazard score. Little information on performance. Lower MDI emission. Similar ingredient exposure potential based on ingredient physical-chemical properties. No cost information available. Does not replace all groups.
BASF Patent No. WO 2019/089237 A1 (example formulation)	Not enough information to definitively assign grouping.	Higher (655), though not enough information to assign group	Higher (295), though not enough information to assign group	Similar (75), though not enough information to assign group	Substantially higher (1,025), though not enough information to assign group	No (no data available)	MDI detected during application with ventilation was lower, similar, and higher compared to the generic Priority Products. Not enough information to assign grouping. No statement regarding PPE requirements found in the patent.	No data available on air, water, soil, sediment, or groundwater (*via* migration from soil/sediment) exposure potential, other than for MDI.	No data available for comparison	Not suitable substitute: Substantially higher hazard score. No information on performance or ingredient exposure potential (other than MDI). Variable reports of MDI emission. No cost information available. Does not replace all groups.

Notes:

ACH = Air Changes Per Hour; MDI = Methylene Diphenyl Diisocyanate; N/A = Not Applicable; PPE = Personal Protective Equipment; ppm = Parts Per Million; SPF = Spray Polyurethane Foam; US EPA = United States Environmental Protection Agency.

(1) We used criteria from US EPA's "Interpretive Assistance Document for Assessment of Discrete Organic Chemicals" (US EPA, 2013) for the evaluation of ingredients' exposure potential in air, water, soil, sediment, and groundwater *via* soil and sediment. See Section 5.3.2. for more information.

Legend:

Dark red	Substantially Higher than Priority Products
Red	Higher than Priority Products or Did Not Meet Performance Criteria
Yellow	Similar to Priority Products
Light green	Lower than Priority Products
Green	Substantially Lower than Priority Products
Grey	Not Applicable: No Comparison Data Available
Red/green gradient	Higher and Lower than Priority Products

Figures

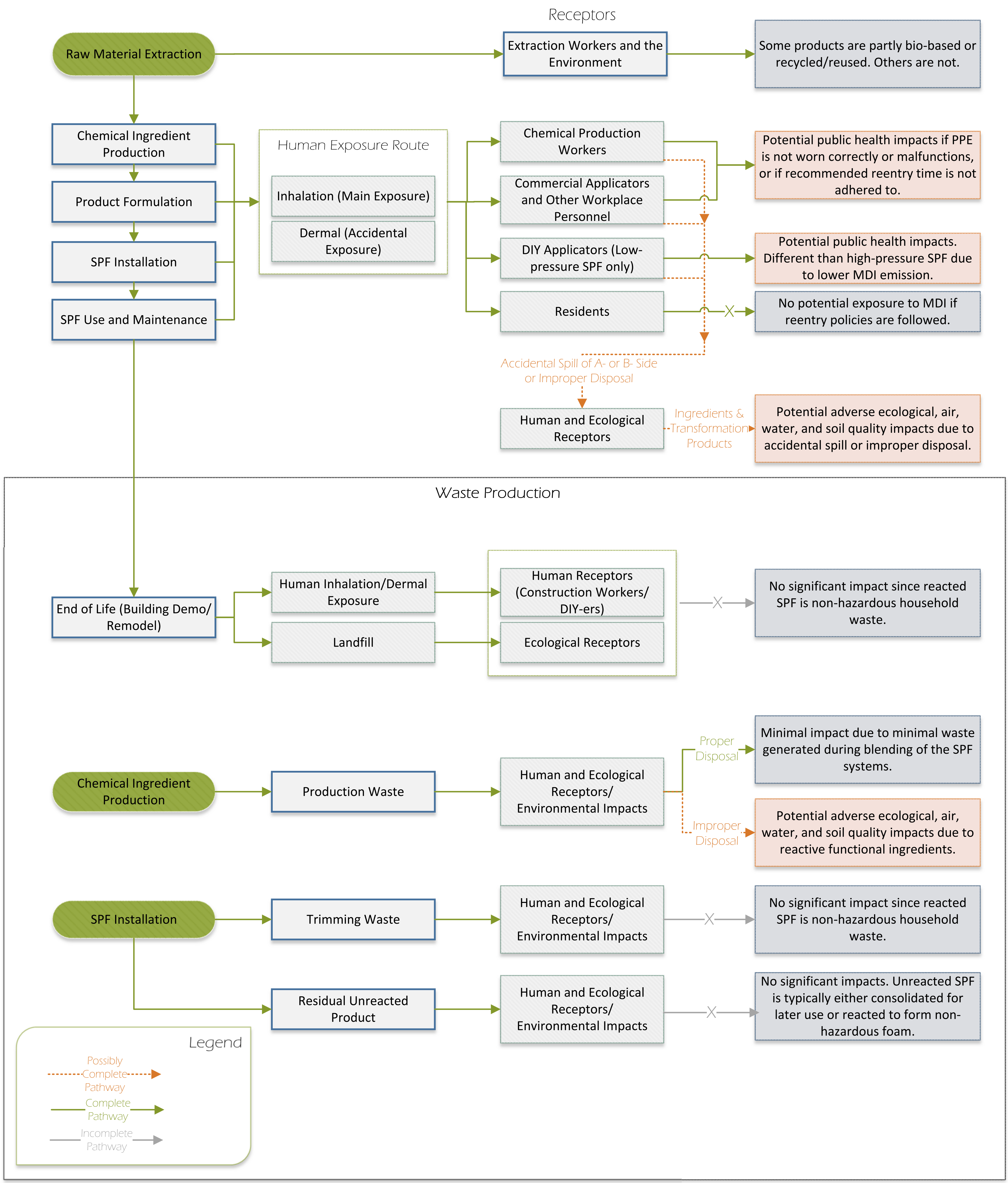

Figure 4.1 Conceptual Exposure Model: Functional Ingredients in pMDI/MDI-based SPF

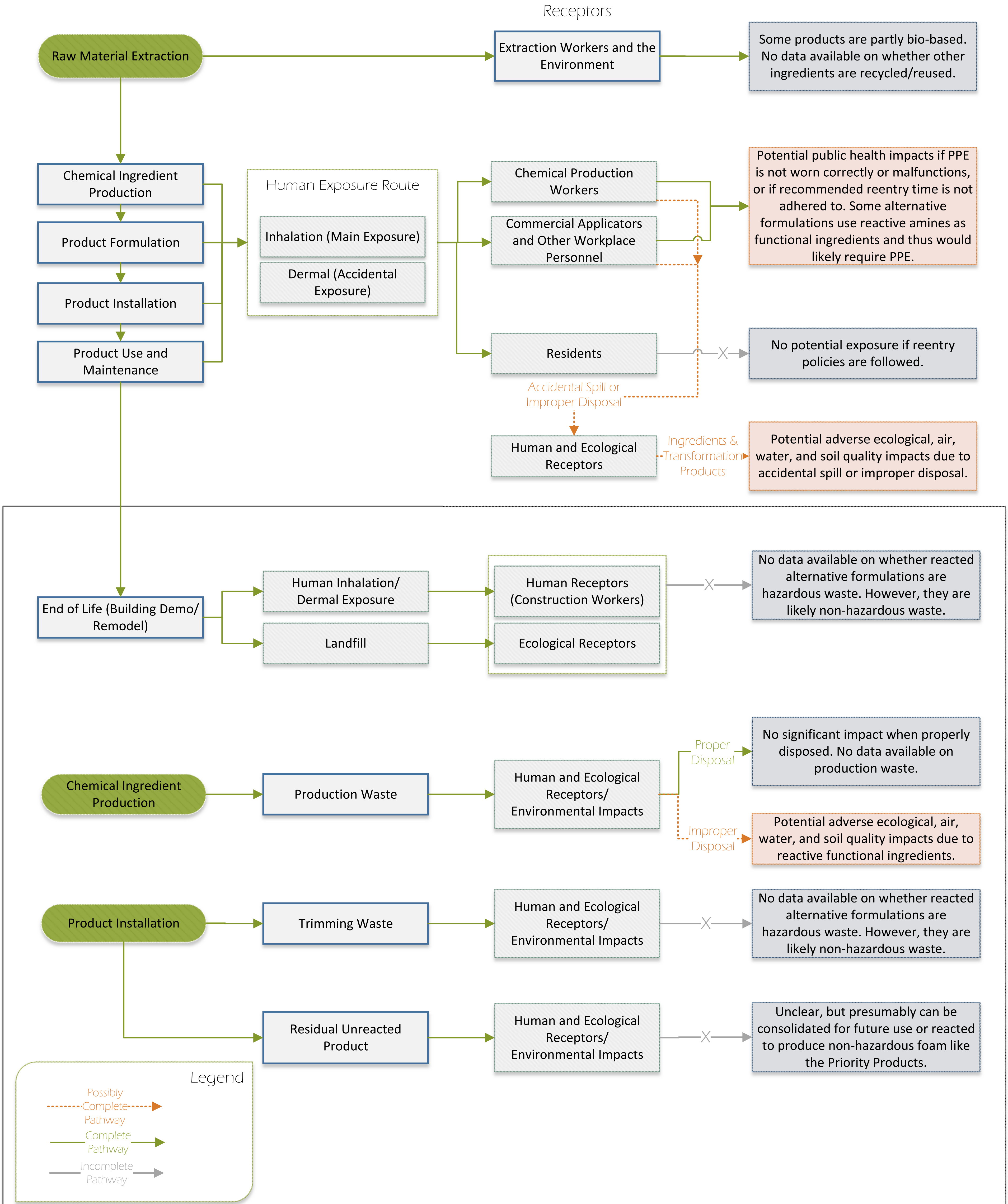

Figure 4.2 Conceptual Exposure Model: Functional Ingredients in Non-pMDI/MDI-based Alternative Formulations

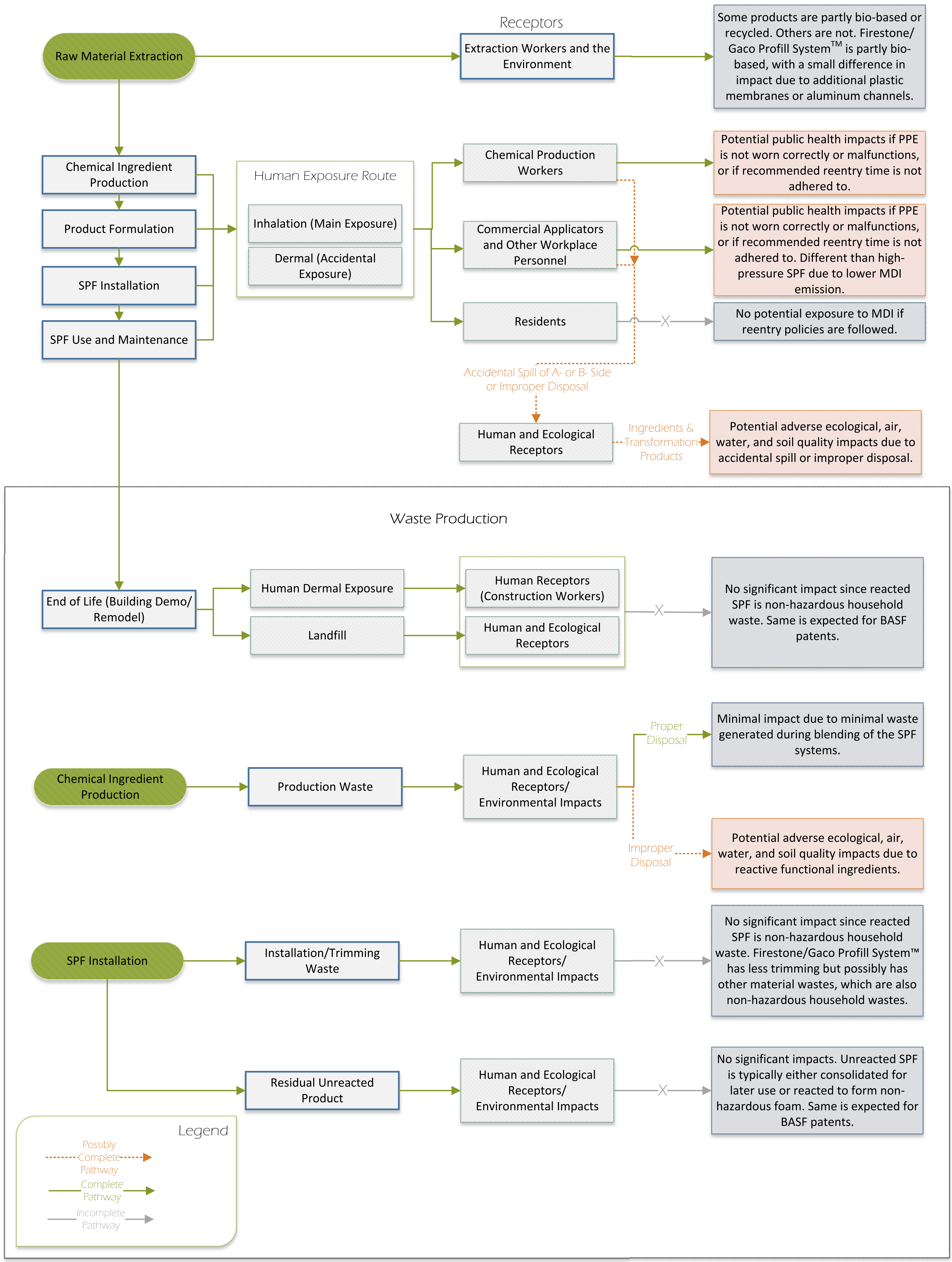

Figure 4.3 Conceptual Exposure Model: Functional Ingredients in Lower-Exposure pMDI/MDI-based Approaches

Appendix C

Product Grouping Information on Existing Priority Products

Table C.1 Manufacturers of Low- and High-pressure Two-component SPF Products Containing Unreacted MDI Currently for Sale in California

Manufacturer Name	Product Name	Density (lb/f^3)	Pressure	Group[1]
Accella Polyurethane Systems[2]	FOAMSULATE 220 SERIES	2	High	3
Accella Polyurethane Systems	FOAMSULATE 210 SERIES	2	High	3
Accella Polyurethane Systems	Foamsulate 50 NIB	0.5	High	2
Accella Polyurethane Systems	BAYSEAL OC	0.45-0.5	High	2
Accella Polyurethane Systems	BAYSEAL OC X	0.6	High	2
Accella Polyurethane Systems	BAYSEAL CC X	2	High	3
Accella Polyurethane Systems	BAYSEAL 2.7 Series	2.7	High	3
Accella Polyurethane Systems	BAYSEAL 3.0 Series	3	High	4
Accella Polyurethane Systems	QuadFoam NatureSeal OCX	0.5	High	2
Accella Polyurethane Systems	Bayseal OC HY	0.45-0.5	High	2
Accella Polyurethane Systems	QuadFoam 2.0	2	High	3
Accella Polyurethane Systems	QuadFoam 500	0.5	High	2
Accella Polyurethane Systems	Premipour 202M	2.0	High	3
Accella Polyurethane Systems	PREMISEAL 40 SERIES	2.5	High	3
Accella Polyurethane Systems	PREMISEAL 60 SERIES	2.8	High	3
Accella Polyurethane Systems	PREMISEAL 70 SERIES[3]	3	High	4
Accella Polyurethane Systems	PREMISEAL 80 SERIES[3]	3	High	4
Accella Polyurethane Systems	PREMISEAL 250 SERIES	2.5	High	3
Accella Polyurethane Systems	PREMISEAL 255 SERIES	2.5	High	3
Accella Polyurethane Systems	PREMISEAL 280 SERIES	2.8	High	3
Accella Polyurethane Systems	PREMISEAL 285 SERIES	2.8	High	3
Accella Polyurethane Systems	PREMISEAL 300 SERIES	3	High	4
Accella Polyurethane Systems	PREMIR+ 60 SERIES	2.8	High	3
Accella Polyurethane Systems	PREMIR+ 40 SERIES	2.5	High	3
Accella Polyurethane Systems	FOAMSULATE CLOSED CELL SERIES	2	High	3
Accella Polyurethane Systems	FOAMSULATE HFO SERIES	2	High	3
Accella Polyurethane Systems	FOAMSULATE 50 HY	0.5	High	2
Accella Polyurethane Systems	FOAMSULATE 50	0.5	High	2
Accella Polyurethane Systems	FOAMSULATE OCX	0.5	High	2
Accella Polyurethane Systems	FOAMSULATE 70	0.75	High	2
Accella Polyurethane Systems	SEALTITE PRO CLOSED CELL SERIES	2	High	3
Accella Polyurethane Systems	SEALTITE PRO HIGH YIELD	0.45	High	2
Accella Polyurethane Systems	SEALTITE PRO NO MIX	0.5	High	2

Manufacturer Name	Product Name	Density (lb/f^3)	Pressure	Group[1]
Accella Polyurethane Systems	SEALTITE PRO NO TRIM	0.75	High	2
Accella Polyurethane Systems	SEALTITE PRO OCX	0.5	High	2
Accella Polyurethane Systems	SEALTITE PRO ONE ZERO SERIES	2	High	3
Accella Polyurethane Systems	SEALTITE PRO OPEN CELL	0.5	High	2
A&B Filling Inc.	Brand A Product 1	0.75-2.8	Low	1
A&B Filling Inc.	Brand B Product 2	1.75	Low	1
A&B Filling Inc.	Brand C Product 3	2.5	Low	1
A&B Filling Inc.	Brand D Product 4	NA	Low	1
BASF Corp.	Elastospray 81255 SERIES	2.5	High	3
BASF Corp.	Elastospray 81285 SERIES	2.8	High	4
BASF Corp.	Elastospray 81305 SERIES	3.0	High	4
BASF Corp.	Elastospray 8000A	NA	High	NA
BASF Corp.	ENERTITE G	0.50	High	2
BASF Corp.	ENERTITE NM	0.50	High	2
BASF Corp.	FE 348-2.5 SERIES	2.5	High	3
BASF Corp.	FE 348-2.8 SERIES	2.8	High	4
BASF Corp.	FE 348-3.0 SERIES	3.0	High	4
BASF Corp.	SKYTITE 2.5	2.5	High	3
BASF Corp.	SKYTITE 2.8	2.8	High	4
BASF Corp.	SKYTITE 3.0	3.0	High	4
BASF Corp.	SPRAYTITE 158	2.0	High	3
BASF Corp.	SPRAYTITE 178 SERIES	2.0	High	3
BASF Corp.	SPRAYTITE 180 SERIES	2.0	High	3
BASF Corp.	SPRAYTITE 81206 SERIES	2.0	High	3
BASF Corp.	SPRAYTITE SP	2.0	High	3
BASF Corp.	WALLTITE US SERIES	2.0	High	3
BASF Corp.	WALLTITE HP+	2.0	High	3
BASF Corp.	BASF CBI - #1	NA	Low	1
BASF Corp.	BASF CBI - #2	0.5	Low	1
BASF Corp.	BASF CBI - #3	2.0	Low	1
BASF Corp.	BASF CBI - #4	NA	High	NA
BASF Corp.	BASF CBI - #5	2.5	High	3
BASF Corp.	BASF CBI - #6	2.8	High	4
BASF Corp.	BASF CBI - #7	3.0	High	4

Manufacturer Name	Product Name	Density (lb/f^3)	Pressure	Group[1]
BASF Corp.	BASF CBI - #8	NA	High	NA
BASF Corp.	BASF CBI - #9	2.5	High	3
BASF Corp.	BASF CBI - #10	2.8	High	4
BASF Corp.	BASF CBI - #11	3.0	High	4
BASF Corp.	BASF CBI - #12	NA	High	NA
BASF Corp.	BASF CBI - #13	2.8	High	4
BASF Corp.	BASF CBI - #14	3.0	High	4
BASF Corp.	BASF CBI - #15	NA	High	NA
BASF Corp.	BASF CBI - #16	2.5	High	3
BASF Corp.	BASF CBI - #17	2.8	High	4
BASF Corp.	BASF CBI - #18	3.0	High	4
DAP Products, Inc.	Touch n' Seal Fire-Rated 1.75 PCF Slow Rise Polyurethane Foam Sealant	1.75	Low	1
DAP Products, Inc.	Touch n' Seal 1.75 PCF ICC Closed Cell Polyurethane Foam Sealant	1.75	Low	1
DAP Products, Inc.	Touch n' Seal 2.0 PCF Fire-Rated Polyurethane Foam Sealant	2	Low	1
DAP Products, Inc.	Touch n' Seal 3.0 PCF High Density Closed Cell Polyurethane Foam Sealant	3	Low	1
DAP Products, Inc.	Touch n' Seal Mine Foam Sealant	1.75	Low	1
DAP Products, Inc.	Touch n' Foam Professional Fire-Rated 1.75 PCF CCMC Closed Cell Polyurethane Foam Sealant	1.75	Low	1
DAP Products, Inc.	Touch n' Foam Fire-Rated 1.75 PCF Closed Cell ICC Polyurethane Foam Sealant	1.75	Low	1
DAP Products, Inc.	Touch n' Seal Fire-Rated Low Density 1.0 PCF Open Cell Polyurethane Foam Sealant	1	Low	1
DAP Products, Inc.	Touch n' Seal 1.75 PCF Fire Rated PCF CCMC Closed Cell Polyurethane Foam Sealant	1.75	Low	1
Demilec	Agribalance	0.6-0.8	High	2
Demilec	Demilec APX Series	0.45-0.5	High	2
Demilec	Heatlok HFO High Lift	2-2.4	High	3
Demilec	Heatlok HFO Pro	2-2.4	High	3
Demilec	Heatlok Soy 200+	2.1	High	3
Demilec	Heatlok XT	2.2	High	3
Demilec	Sealection 500	0.52	High	2
DuPont	FrothPak™ Sealant and Insulation	1.75	Low	3
DuPont	FrothPak™ Ultra Insulation	2.3	Low	1
DuPont	Styrofoam™ Dow 3019 with CM2045	2.3	High	3

Manufacturer Name	Product Name	Density (lb/f^3)	Pressure	Group[1]
Firestone	F1800 – GacoTrenchFoam – Polyol Component B	No info. provided	High	No info. provided
Firestone	F-CF2030 – GacoPourFoam CF2030 – Polyol Component B	2	High	3
Firestone	FB28-120 – GacoFlashFoam – Component A & B	2.5	Low	1
Firestone	F10000 – GacoToughFoam – Polyol Component B	10	High	4
Firestone	F183M – Gaco 183M– Polyol Component B	1.8	High	3
Firestone	F1850R – GacoOnePass – Polyol Component B	1.8	High	3
Firestone	F052N – Gaco 052N GacoInsulBarrier – Polyol Component B	0.5	High	2
Firestone	F5001 –GacoFireStop 2 – Polyol Component B	0.6	High	2
Firestone	F4500R – GacoEZSpray – Polyol Component B	0.5	High	2
Firestone	FR6500R – GacoProFill – Polyol Component B	0.6	High	2
Firestone	F1880R – GacoOnePass Low GWP – Polyol Component B	1.8	High	3
Firestone	F2733R – GacoRoofFoam – Polyol Component B	2.7	High	4
Firestone	F2780 – Polylol Component B	2.7-3.4	High	4
Firestone	ISO – Isocyanate – Iso Component A	NA	High	NA
General Coatings Manufacturing Corp.	Brand A 1, 2.5	2.5	High	3
General Coatings Manufacturing Corp.	Brand A 2, 2.7	2.7	High	4
General Coatings Manufacturing Corp.	Brand A 3, 3.0	3.0	High	4
General Coatings Manufacturing Corp.	Brand B 1, 2.5	2.5	High	3
General Coatings Manufacturing Corp.	Brand B 2, 2.7	2.7	High	4
General Coatings Manufacturing Corp.	Brand B 3, 3.0	3.0	High	4
General Coatings Manufacturing Corp.	Ultra-Thane 050	0.5	High	2
General Coatings Manufacturing Corp.	Ultra-Thane 050 OCX	0.5	High	2
General Coatings Manufacturing Corp.	Ultra-Thane 170 Pour Foam	2	Low	1
General Coatings Manufacturing Corp.	Ultra-Thane 230-2.0	2	High	3
General Coatings Manufacturing Corp.	Ultra-Thane 230-2.5, 2.7, and 3.0 Roof Foam	2	High	3
General Coatings Manufacturing Corp.	Universal Polymers Corp 2.0	2.15	High	3
General Coatings Manufacturing Corp.	Universal Polymers Corp 500	0.5	High	2
General Coatings Manufacturing Corp.	Universal Polymers Corp 500 OCX	0.5	High	2
Henry Company LLC	Permax Closed-cell Foam Insulation Series	1.8-2.5	High	3
ICP Adhesives & Sealants	Handi-Foam® E84 Spray Foam	2.12	Low	1
ICP Adhesives & Sealants	Handi-Foam® Quick Cure	2.12	Low	1
ICP Adhesives & Sealants	Handi-Foam® Air Seal	2.12	Low	1
ICP Adhesives & Sealants	Handi-Foam® Low Density	0.75	Low	1

Manufacturer Name	Product Name	Density (lb/f³)	Pressure	Group[1]
ICP Adhesives & Sealants	Handi-Foam® Wall Seal	0.75	Low	1
ICP Adhesives & Sealants	Brand A Product 1	2.12	Low	1
ICP Adhesives & Sealants	Brand B Product 1	2.12	Low	1
ICP Adhesives & Sealants	Brand B Product 2	2.12	Low	1
ICP Adhesives & Sealants	Brand B Product 3	1.12	Low	1
Icynene-Lapolla	Icynene Classic Plus™	0.7	High	2
Icynene-Lapolla	Icynene Classic™	0.5	High	2
Icynene-Lapolla	Icynene Classic Eco	0.5	High	2
Icynene-Lapolla	Icynene Classic Max	0.5	High	2
Icynene-Lapolla	Icynene MDC 200 V6	2.4	High	3
Icynene-Lapolla	Icynene MDR 210	2.2	High	2
Icynene-Lapolla	ProSeal Eco	2.2	High	3
Icynene-Lapolla	Icynene ProSeal	2-2.4	High	3
Icynene-Lapolla	Lapolla Foam-LOK FL500	0.5	High	2
Icynene-Lapolla	Lapolla Foam-LOK FL2000	2.0	High	3
Icynene-Lapolla	Lapolla Foam-LOK FL2000 – 4G	2.0	High	3
Icynene-Lapolla	Lapolla Foam-LOK LPA 2500	2.5	High	3
Icynene-Lapolla	Lapolla Foam-LOK LPA 2800	2.8	High	4
Johns Manville[4]	JM Corbond III® SPF	2	High	3
Johns Manville	JM Corbond® oc SPF	0.5	High	2
Johns Manville	JM Corbond® ocx SPF	0.5	High	2
NCFI Polyurethanes[5]	10-011	2.8	High	4
NCFI Polyurethanes	10-013	2.8	High	4
NCFI Polyurethanes	11-016	2	High	3
NCFI Polyurethanes	11-017	2	High	3
NCFI Polyurethanes	11-033	1.7	High	3
NCFI Polyurethanes	11-035	2	High	3
NCFI Polyurethanes	11-036	2	High	3
NCFI Polyurethanes	11-037	2	High	3
NCFI Polyurethanes	12-008	0.4-0.5	High	2
Rhino Linings Corporation	ThermalGuard ISO, A Component	NA	NA	NA
Rhino Linings Corporation	Duratite CC2.5, B Component	2.5	High	3
Rhino Linings Corporation	Duratite CC2.8, B Component	2.8	High	4
Rhino Linings Corporation	Duratite CC3.0, B Component	3.0	High	4

Manufacturer Name	Product Name	Density (lb/f^3)	Pressure	Group[1]
Rhino Linings Corporation	ThermalGuard CC2, B Component	2	High	3
Rhino Linings Corporation	ThermalGuard OC 1.0, B Component	1.0	High	2
Rhino Linings Corporation	ThermalGuard OC 0.5, B Component	0.5	High	2
SES Foam LLC	EasySeal.5 Spray Foam	0.5	High	2
SES Foam LLC	Nexseal™ 2.0, 2.0W, 2.0 LE, 2.0 LE W Spray Foam	2	High	3
SES Foam LLC	SES 2.5, SES 2.5 S, SES 2.5 W Spray Foam	2.5	High	3
SES Foam LLC	SES 2.7, SES 2.7 S, SES 2.7W Spray Foam	2.7	High	4
SES Foam LLC	SES 3.0, SES 3.0 S, SES 3.0W. SES 3.0HCS Spray Foam	3.0	High	4
SES Foam LLC	Sucraseal™ 0.5 lb Spray Foam	0.5	High	2
SWD Urethane	Quik-Shield 100X	0.5	High	2
SWD Urethane	Quik-Shield 106	0.5	High	2
SWD Urethane	Quik-Shield 108	0.4	High	2
SWD Urethane	Quik-Shield 112	2	High	3
SWD Urethane	Quik-Shield 118	2	High	3
SWD Urethane	Quik-Shield 125	3	High	4
SWD Urethane	Quik-Shield 450	2	High	3

Notes:
AA = Alternatives Assessment; CalDTSC = California Department of Toxic Substances Control; dba = Doing Business As; MDI = Methylene Diphenyl Diisocyanate; NA = Not Applicable (due to A-side SDS); SDS = Safety Data Sheet; SPF = Spray Polyurethane Foam.
(1) Groups: 1 = Low Pressure; 2 = High Pressure, 0.5 lb/f^3, Open Cell; 3 = High Pressure, 2 lb/f^3, Closed Cell; 4 = High Pressure, 3 lb+/f^3, Closed Cell.
(2) Accella Polyurethane Systems dba Acella Polyurethane Systems, Carlisle Spray Foam Insulation, Carlisle Roof Foam and Coatings.
(3) PREMISEAL 305 was replaced in May 2019 by PREMISEAL 70. PREMISEAL 350 was replaced in September 2019 by PREMISEAL 80.
(4) While Johns Manville choose to include the names of the three Priority Products in the AA, Johns Manville maintains the confidential business information claim on all other information submitted to CalDTSC.
(5) Barnhardt Manufacturing Company dba NCFI® Polyurethanes.