Chemical and Environmental Justice Impacts in the Life Cycle of Building Insulation

Case Study on Isocyanates in Spray Polyurethane Foam

SEPTEMBER 2022

ENERGY EFFICIENCY FOR ALL
energyefficiencyforall.org

PROJECT TEAM

Rebecca Stamm, Ryan Johnson, Cassidy Clarity, and Teresa McGrath, Healthy Building Network

Veena Singla and Michele Knab Hasson, Natural Resources Defense Council

ABOUT ENERGY EFFICIENCY FOR ALL

Energy Efficiency for All unites people from diverse sectors and backgrounds to collectively make affordable multifamily homes energy and water efficient. We do this work so people in underinvested and marginalized communities—particularly Black, Latino, and other communities of color—can equitably benefit from the health, economic, and environmental advantages of energy and water efficiency. Reducing energy and water use in affordable multifamily housing will improve the quality of life for millions, preserve affordable housing across the country, reduce the energy burden on those who feel it most, and cut carbon pollution.

ABOUT HEALTHY BUILDING NETWORK

Since 2000, Healthy Building Network (HBN) has defined the leading edge of healthy building practices that increase transparency in the building products industry, reduce human exposure to hazardous chemicals, and create market incentives for healthier innovations in manufacturing. We are a team of researchers, engineers, scientists, building experts, and educators, and we pursue our mission on three fronts:

1) Research and policy—uncovering cutting-edge information about healthier products and health impacts;

2) Data tools—producing innovative software platforms that ensure product transparency and catalog chemical hazards; and

3) Education and capacity building—fostering others' capabilities to make informed decisions.

As a nonprofit organization, we do work that broadly benefits the public, especially children and the most marginalized communities, who suffer disproportionate health impacts from exposure to toxic chemicals. We work to reduce toxic chemical use, minimize hazards, and eliminate exposure for all.

ENERGY EFFICIENCY FOR ALL

HBN HEALTHY BUILDING NETWORK KNOW BETTER

Table of Contents

ACKNOWLEDGMENTS

This report was made possible through the generous support of the JPB Foundation. The authors gratefully acknowledge the external reviewers, internal reviewers, colleagues, and partners who supported this study. Many thanks to Elise Marton and Tanja Bos for their skilled help in producing this report.

ABBREVIATIONS AND ACRONYMS

ACS: American Community Survey

CASRN: Chemical Abstracts Service Registry Number

CDR: Chemical Data Reporting

EPA: U.S. Environmental Protection Agency

HCl: Hydrochloric Acid

LCA: Life Cycle Assessment

MDA: Methylenedianiline

MDI: Methylene Diphenyl Diisocyanate or Diphenylmethane Diisocyanate

NIOSH: National Institute for Occupational Safety and Health

OSHA: Occupational Safety and Health Administration

PFAS: Per- and Polyfluoroalkyl Substance(s)

PMDI: Polymeric MDI

PPE: Personal Protective Equipment

SPF: Spray Polyurethane Foam

TCPP: Tris(1-chloro-2-propyl)phosphate

TRI: Toxics Release Inventory

EXECUTIVE SUMMARY

Product manufacturers, policymakers, and professionals in the building industry are paying more attention to the potential health and environmental impacts of building products during installation and use, but there has been less consideration of the important chemical impacts that may occur during other life cycle stages, including contributions to environmental injustice. To address this issue, we used the principles of green chemistry and environmental justice to develop a framework for understanding some of the important life cycle chemical impacts of products, considering the following criteria: avoid hazardous chemicals, prevent accidents, prevent pollution and waste, implement circularity and reduce end-of-life impacts, abide by environmental regulations, and prevent disproportionate and cumulative impacts.

In two separate case studies, we have applied this framework to example chemical inputs for building insulation. While insulation provides many benefits including comfort and energy efficiency, it can also have negative environmental and human health impacts throughout the product life cycle. As more insulation is being installed to improve the energy efficiency of buildings, we must ensure that materials that are safer along the entire life cycle are used. To expand understanding of the life cycle chemical hazards associated with insulation materials, we have examined the primary chemical inputs for two insulation materials: glass fibers in fiberglass insulation and isocyanates in spray foam insulation. We chose these inputs because they are the primary components of a preferred insulation material from a material health perspective (fiberglass) and a material that raises significant concerns during installation and use (spray foam).

In this case study, we consider isocyanates used in spray polyurethane foam (SPF) insulation—methylene diphenyl diisocyanate (MDI) in particular. The companion case study on the life cycle chemical impacts of glass fibers in fiberglass insulation, as well as a fact sheet, are available on Healthy Building Network's website.[a] Our framework and case study findings can help inform decisions in product development, alternatives assessment, material selection, and policy.

The process used to make MDI is complex, involving many manufacturing steps and chemicals (called "process chemicals"). It may be possible to use renewable feedstocks for some process chemicals, but the vast majority are derived solely from crude oil and natural gas. Almost all chemicals used in the production of MDI are hazardous, and MDI itself is a known respiratory sensitizer. Exposure to MDI can

[a] https://healthybuilding.net/reports

result in lung irritation or sensitization such that future exposure to small quantities can trigger asthma, inflammation, or other allergic reactions in the respiratory system.

The four facilities that manufacture most of the MDI in the United States are in Texas and Louisiana, and they collectively report releasing an average of almost 560,000 pounds of hazardous MDI-related chemicals to air and water every year. They also report releasing or disposing of large quantities of hazardous chemical waste associated with MDI production—an average of 47.7 million pounds per year. Most of this is disposed of on site, including through incineration, which can lead to additional hazardous releases. MDI facilities have a history of noncompliance with U.S. Environmental Protection Agency regulations.

The MDI manufacturing supply chain includes upstream facilities that provide process chemicals and downstream facilities that incinerate hazardous chemical waste generated during manufacturing. MDI manufacturing and supply chain facilities are sited in communities that are disproportionately Black, Latino, and/or American Indian or Alaska Native. For example, Latinos make up 18 percent of the U.S. population overall but more than double that percentage in the combined areas surrounding MDI manufacturing facilities. These fenceline communities also have a greater proportion of children than in the United States overall—about 30 percent versus 23 percent. Two of the four MDI facilities also have schools located in close proximity, so children may be exposed to hazardous releases both where they live and where they learn. Incidents at facilities throughout the manufacturing supply chain have injured workers and resulted in shelter-in-place orders for nearby communities. The MDI manufacturing plants are in cities with a large number of other facilities that also manage or release hazardous chemicals, contributing to cumulative impacts for the surrounding communities.

Spray foam insulation products are intended to last the lifetime of a building, or about 75 years. At the end of its life, SPF is not reused or recycled. It is typically disposed of in landfills or may be burned in intentional incineration or accidental fires, releasing toxic chemicals. The release of toxic chemicals from landfills or incinerators impacts surrounding communities.

Table 8 summarizes our findings regarding the life cycle chemical impacts associated with MDI, along with recommendations for reducing these impacts.

Manufacturers throughout the life cycle of insulation products should implement green chemistry and environmental justice principles. Because most of the input and output chemicals for MDI production are hazardous, there is little opportunity for improvements in this existing manufacturing process. There are also limited opportunities to improve from a circularity perspective. The biggest opportunity for both manufacturing and end of life is to move to different, nonhazardous chemistries or materials to achieve the same function. Beyond this, manufacturers should:

- Reduce waste and releases beyond regulatory limits by optimizing process efficiency and using safer inputs;
- Avoid expanding or building new facilities that will increase hazardous chemical releases in already disproportionately impacted communities;
- Assess and improve the social equity impacts of their products and organizations; and
- Provide disclosure about material content, emissions, and location of manufacture.

Policymakers should also support the implementation of green chemistry and environmental justice principles. They should:

- Increase facility inspections and penalties for violations;
- Strengthen the Risk Management Plan (RMP) Rule to increase information and protections for people who live and work near high-risk chemical facilities;
- Implement mandates on emissions reduction;
- Implement policies that support the development of products that can safely be reused and recycled as part of a circular economy; and
- Adopt policies that account for cumulative impacts in permitting decisions.

Building industry professionals can demand transparency about what is in a product, how it is made, and the hazardous releases that occur throughout its life cycle. As a starting point in considering the embodied chemical impacts of products, they should avoid products containing hazardous chemicals.

All these actions help support a more equitable and sustainable built environment.

INTRODUCTION

Purpose of Case Study and Framework for Analysis

Since the early days of the contemporary green building movement several decades ago, green building has been synonymous with improving building energy performance. Building material decisions are driven largely by energy efficiency and monetary cost considerations. More recently, building industry professionals have started including the embodied carbon of materials as an additional metric that is relevant to a building's climate change impacts; embodied carbon refers to the greenhouse gases emitted during life cycle stages outside of product use, such as raw material extraction, product manufacturing, transportation, and end of life.[1] However, human health and environmental impacts beyond carbon emissions can also occur at each life cycle stage. Unfortunately, this perspective is often missing or underrepresented when the green and sustainable building community considers building material impacts. Workers, building occupants, communities surrounding manufacturing facilities or extraction sites, and the broader environment can all be affected by hazardous chemicals during raw material extraction, chemical and product manufacturing, installation, use, and disposal or recycling, as illustrated in Figure 1. If we do not account for the effects of embodied chemicals, we won't understand the true impacts of materials on human and environmental health, and importantly, who is bearing the burden of these impacts. Buildings and products shouldn't be considered "green" unless they are green for all.

FIGURE 1. Product life cycle
(adapted from UNEP "Life Cycle Management: A Business Guide to Sustainability"[2])

This case study aims to expand general understanding of the life cycle chemical hazards associated with building products using an example chemical and building material. The analysis is focused on health and environmental justice impacts related to chemical inputs and outputs in the context of the principles of green chemistry and environmental justice (Appendix 1). The U.S. Environmental Protection Agency (EPA) defines green chemistry as "the design of chemical products and processes that reduce or eliminate the use or generation of hazardous substances" throughout the product life cycle. It defines environmental justice as "the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income, with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies."[3] Using these principles as a starting point, we identified six major criteria for considering chemical and environmental justice impacts: avoid hazardous chemicals, prevent accidents, prevent pollution and waste, implement circularity and reduce end-of-life impacts, abide by environmental regulations, and prevent disproportionate and cumulative impacts (Table 1). Several of these criteria are derived from both the principles of green chemistry and the principles of environmental justice. However, there are some environmental justice concepts that are not covered within the principles of green chemistry—in particular the idea of universal protection from toxics for all people.

Table 1. Case study criteria for assessing chemical and environmental justice impacts based on selected green chemistry and environmental justice principles		
Principles of green chemistry*	**Principles of environmental justice***	**Case study criteria for assessing chemical and environmental justice impacts**
■ Designing chemicals, processes, and products with little or no toxicity to humans or the environment ■ Using inherently safer chemistry to minimize potential for chemical accidents	■ Ceasing the production of all toxics ■ Ensuring the right of all workers to a safe and healthy work environment	**Avoid hazardous chemicals**
■ Using inherently safer chemistry to minimize potential for chemical accidents	■ Ensuring the right of all workers to a safe and healthy work environment	**Prevent accidents**
■ Preventing pollution and waste	■ Protecting all people from extraction, production, and disposal of toxics and hazardous wastes that threaten the fundamental right to clean air, land, water, and food	**Prevent pollution and waste**
■ Using starting materials that are renewable instead of depletable	■ Protecting all people from extraction, production, and disposal of toxics and hazardous wastes that threaten the fundamental right to clean air, land, water, and food	**Implement circularity and reduce end-of-life impacts**
	■ Protecting all people from extraction, production, and disposal of toxics and hazardous wastes that threaten the fundamental right to clean air, land, water, and food	**Abide by environmental regulations**
	■ Basing public policy on mutual respect and justice for all peoples, free from any form of discrimination or bias ■ Affirming the fundamental right to self-determination for all peoples ■ Protecting all people from extraction, production, and disposal of toxics and hazardous wastes that threaten the fundamental right to clean air, land, water, and food	**Prevent disproportionate and cumulative impacts**

*See Appendix 1 for the full Principles of Green Chemistry and Principles of Environmental Justice.

Scope of Case Study

This case study supports the work of Energy Efficiency for All, which advocates for the use of safer materials for energy efficiency upgrades in affordable housing.[4] We chose to consider the life cycle chemical impacts of insulation materials because insulation is a critical component of almost all new construction and many energy-efficiency upgrades and helps provide comfortable and energy-efficient buildings.

While insulation provides many benefits, it may also introduce hazardous chemicals into buildings.[5] Given the large quantity of insulation used, material decisions can cumulatively affect the amount of toxic substances brought into building spaces and the embodied chemical impacts throughout the life cycle. Building insulation is a very broad product category that includes a variety of material types—such as cellulose, glass and mineral fiber, plastic foam, and natural materials—that are used in a range of forms: batt, blown, sprayed, and board. Our prior work evaluated use-phase chemical impacts of common insulation materials and found that, from this material health perspective, fiberglass ranks well while spray foam raises significant hazardous chemical concerns. Building on that work, we now consider the life cycle chemical impacts of the primary chemical inputs for these two insulation materials: glass fibers in fiberglass insulation and isocyanates in spray foam insulation.

This case study expands the understanding of life cycle chemical hazards associated with isocyanates used in spray foam insulation. We consider chemicals that may be used in the production of isocyanates for spray foam insulation and their health hazards, as well as potential exposures throughout the manufacturing supply chain in the United States. We also review the most common end-of-life scenarios for spray foam insulation. We used publicly available information to compare how isocyanates in spray foam insulation align with or diverge from our criteria for chemical and environmental justice impacts.

This report includes a brief discussion of some of the impacts on the communities where manufacturing takes place and equity implications within the supply chain, but it should not be considered a complete discussion of social or environmental justice issues related to isocyanate production or spray foam insulation. This analysis does not include consideration of life cycle greenhouse gas emissions or other broad life cycle assessment (LCA) criteria. Nor does it address material cost, performance, or availability. For additional information on the range of chemical contents of building insulation materials including spray foam insulation, potential impacts during installation and use, and recommendations for safer materials, see "Making Affordable Multifamily Housing More Energy Efficient: A Guide to Healthier Upgrade Materials."[6]

Background on Spray Foam Insulation

Rigid spray polyurethane foam insulation (SPF) is a product made of two components (sometimes called the "A side" and "B side") that are combined and reacted on site as the insulation is installed in a building. The first component, making up about 50 percent of the product, is composed of methylene diphenyl diisocyanate (MDI) and its polymer form, PMDI. The second component is composed of additional reactive chemicals, blowing agents, and flame retardants. SPF is used in residential, commercial, and industrial applications to insulate interior or exterior walls, attics, ceilings, and crawl spaces and can also be used as part of a roofing system.[7]

The global spray foam insulation market has grown rapidly in the past decade or so, from an estimated $800 million (U.S. dollars) in 2013 to an expected $2.1 billion by 2025.[8] Residential applications account for the largest portion of use, and North America is the largest market.[9] In 2015, 460 million to 490 million pounds of SPF were used in the United States and Canada for roofing and insulation.[10] According to a 2019 survey of U.S. home builders, spray foam insulation accounted for about 11 percent of the square footage of insulation installed in new single-family homes.[11] In some regions, use of SPF may be growing more rapidly due to incentives for energy efficiency upgrades, combined with SPF's high insulative performance and air-sealing properties.[12] Surveys conducted by Energy Efficiency for All in 2019 suggest that foam insulation, including SPF, is less commonly used in low-income housing upgrades because of its higher cost relative to other insulation materials.[13]

Background on MDI as a Key Ingredient of Spray Foam Insulation

Isocyanates are a key component of polyurethane and are used in the production of a wide range of materials, including rigid polyurethane foam (such as insulation for buildings and refrigeration systems), flexible polyurethane foam (used in furniture cushions, mattresses, and car seats), binders (used in composite wood), adhesives and sealants, and coatings.[14] MDI is one of the most commonly used isocyanates.[15]

In 2018 the global production of MDI was about 9.8 million metric tons (more than 21 billion pounds), with expected growth of 3.5 percent to 5.5 percent per year in the coming years.[16] About 80 percent of global MDI production is used in polyurethane foams, with rigid foam being the largest use.[17]

Isocyanates, including MDI, are globally recognized as respiratory sensitizers.[18] This means that exposure can result in lung irritation or sensitization such that future exposure to small quantities can trigger asthma, inflammation, or other allergic reactions in the respiratory system. Organizations like the U.S. Occupational Safety and Health Administration (OSHA) have identified isocyanates as a leading cause of work-related asthma.[19] While reported incidences have declined in recent years, limited data are available to gauge the scope of the issue.[20] Once someone has been sensitized to MDI, even very low exposures may trigger severe asthma attacks.[21] While many products that use MDI are reacted within a factory setting to form the polyurethane material, spray foam insulation contains unreacted MDI, and the reaction takes place as the product is installed in a building.[22] This increases the potential for installers and others present to be exposed. See the "Installation and Use Phase" text box later in this report for more information.

CHEMICAL CONSIDERATIONS IN MDI MANUFACTURING

Production

While much is known about the hazards of isocyanates themselves, less is reported about the hazards associated with the raw materials and processes used to manufacture them. This section considers chemicals used throughout the MDI manufacturing process.

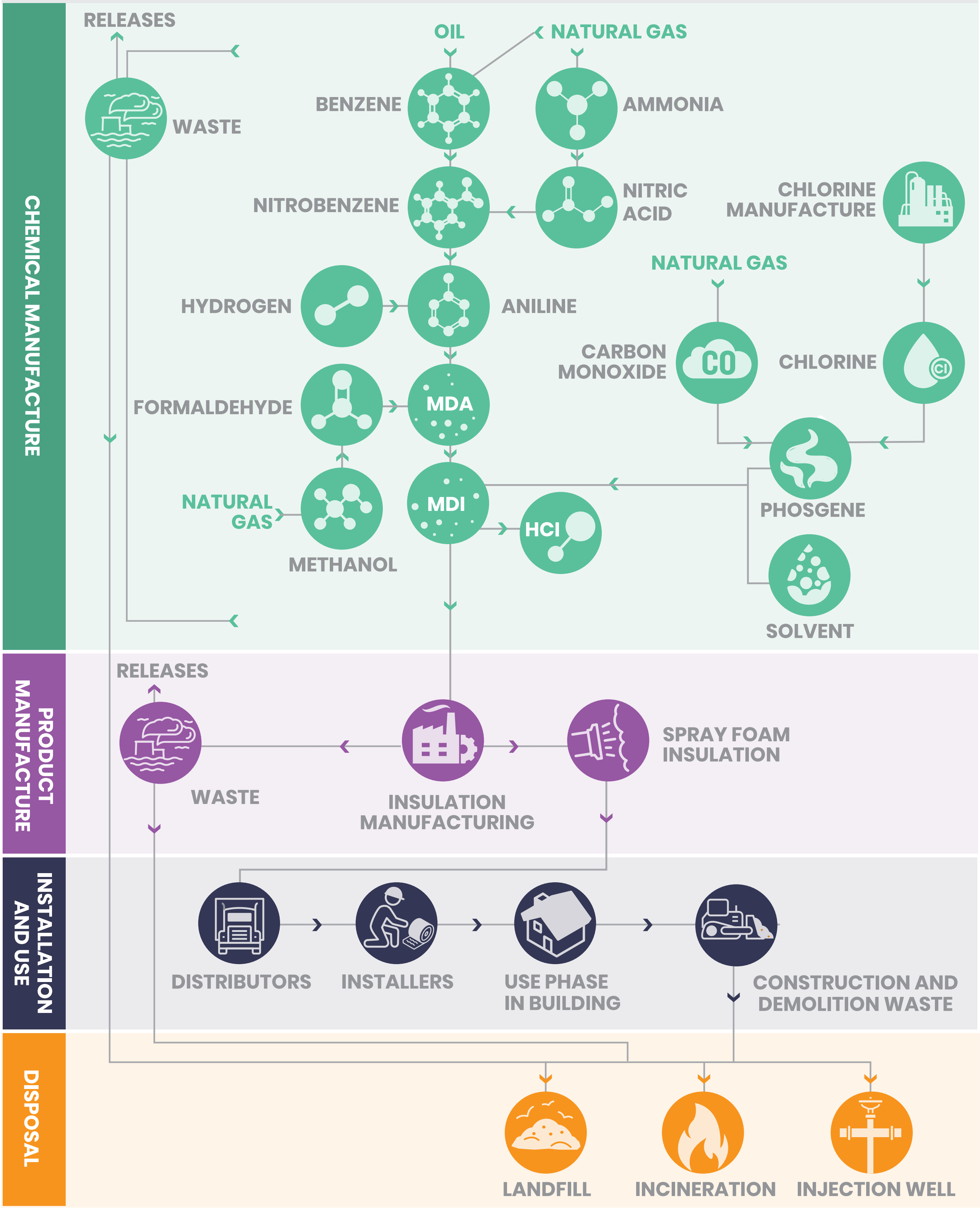
Making MDI is a complex process, using a large number of chemicals and many manufacturing steps, as outlined in Figure 2. The raw materials for MDI production come largely from crude oil and natural gas. Key primary chemicals include benzene, nitric acid, formaldehyde, methanol, hydrogen, chlorine, and carbon monoxide. These chemicals are used to generate nitrobenzene, aniline, methylenedianiline (MDA), phosgene, and ultimately MDI.[23] A solvent, such as chlorobenzene or xylene, may be used for the reaction of MDA and phosgene.[b] Hydrochloric acid (HCl) is a by-product of the reaction process.[24]

We found no recycled feedstocks for MDI. It is technically possible to use renewable feedstocks for some chemicals involved in the production of MDI, and some manufacturers may use recycled or renewable material for part of the second component (B side) of two-part SPF insulation.[25] Still, the vast majority of polyurethane materials manufactured today are derived solely from petroleum.[26]

We did not consider the energy required for the manufacture of MDI in this case study.

[b] Because we do not know which solvent(s) may be used for this process in the facilities considered in this case, solvents are left out of the subsequent analysis.

FIGURE 2. Life cycle of MDI production and SPF manufacture, installation, use, and end of life.[27] Graphic shows elements of the life cycle discussed in this case study.



Chemical Hazards

In this section, we consider the chemical hazards of the inputs and releases related to MDI production. When hazardous chemicals are used, they can impact people and the environment throughout their life cycle. Workers who extract these materials, process them, and use them to manufacture products, as well as communities near facilities where each step of the process takes place, can be impacted. See the "Worker and Fenceline Community Impacts" section for some example impacts.

Almost all the chemicals used in the production of MDI are hazardous. Several are carcinogens or asthmagens. For example, ammonia is designated as an asthmagen by the Association of Occupational and Environmental Clinics.[28] Aniline is recognized as a probable carcinogen by the EPA and the International Agency for Research on Cancer, an agency of the World Health Organization.[29] Benzene is linked to cancer and gene mutation by a range of international organizations.[30] Most of the chemicals used in the production of MDI are also considered acutely toxic, meaning that they can be fatal on contact, ingestion, or inhalation. Many of the chemicals are also highly reactive or flammable. Highly reactive chemicals can spontaneously ignite or explode on their own or in contact with water, and flammable chemicals are easily ignited and capable of burning rapidly. Chemicals that are highly reactive or flammable can contribute to the potential for incidents that can impact workers and surrounding communities. Most of the chemicals used in the process are also volatile. Volatile chemicals easily evaporate at normal temperatures and may increase the potential for exposure compared with less volatile or nonvolatile chemicals. Exposure to volatile organic compounds (VOCs) can cause immediate symptoms such as respiratory irritation, as well as longer-term health effects.[31] VOCs also contribute to the formation of smog.[32]

A more complete list of the hazards associated with each of these chemicals and MDI variations is given in Table 2. Descriptions of each health hazard endpoint are provided in Table 3.

Table 2. Selected chemical hazards of primary chemicals, intermediates, and by-products in the manufacture of MDI and of MDI variations used in SPF.[33]

CASRN	Chemical Name	Volatile Chemical†	Carcinogen, Mutagen, Reproductive or Developmental Toxicant, and/or Endocrine Disruptor	Respiratory Sensitizer	Acutely Toxic Chemical	Reactive Chemical	Flammable Chemical	TRI Reportable Chemical	Reported as a TRI Release by MDI Facilities in the Last 5 Years
Primary Chemicals and Intermediates									
71-43-2	Benzene	x	x				x	x	x
7664-41-7	Ammonia	x		x	x			x	x
7697-37-2	Nitric acid	x			x			x	x
98-95-3	Nitrobenzene	x	x		x			x	x
62-53-3	Aniline	x	x		x			x	x
1333-74-0	Hydrogen	x					x		
67-56-1	Methanol	x	x		x		x	x	x
50-00-0	Formaldehyde	x	x	x	x		x	x	x
630-08-0	Carbon monoxide	x	x		x		x		
7782-50-5	Chlorine	x		x	x	x		x	x
75-44-5	Phosgene	x			x			x	x
101-77-9	4,4'-Methylenedianiline (MDA)		x		x			x	x
By-products									
7647-01-0	Hydrochloric acid	x			x			x	x
MDI Variations Used in SPF Insulation									
101-68-8	4,4'-Diphenylmethane diisocyanate			x				x*	x*
9016-87-9	Polymethylene polyphenyl isocyanate (PMDI)			x	x			x*	x*
5873-54-1	2,4'-Diphenylmethane diisocyanate			x					
26447-40-5	Diphenylmethane diisocyanate			x					
2536-05-2	Diphenylmethane-2,2'-diisocyanate			x					

None of the listed chemicals are considered to be persistent, bioaccumulative, and toxic (PBTs). (See “Chemical Hazards” text box for more information.)

* Included in TRI reporting of the chemical group diisocyanates.

† The variations of MDI typically decompose before boiling point can be determined. Isocyanates are commonly considered semi-volatile organic compounds.

Chemical Hazards

Hazard assignments in Table 2 are based on either a full hazard assessment or on a review of health hazard lists from the GreenScreen for Safer Chemicals.[34] Hazard indicators are included for chemicals assigned a high hazard for carcinogen, mutagen, reproductive or developmental toxicant, or endocrine disruptor; a high or a moderate-to-high hazard for respiratory sensitizer; and a high or very high hazard for acute toxicity. Reactivity and flammability contribute to potential safety issues with the use of these chemicals so are also indicated for chemicals with a high or very high hazard. Descriptions of each hazard are provided in Table 3.

Table 3. Human health and physical hazards and descriptions

Hazard	Description
Carcinogen	Can cause cancer or contribute to the development of cancer.
Mutagen	Can cause or increase the rate of mutations, which are changes in genetic material in cells that in some cases may be transmitted to offspring. This can result in cancer and birth defects.
Reproductive Toxicant	Can disrupt the male or female reproductive system—changing sexual development, behavior, or functions; decreasing fertility; or resulting in loss of the fetus during pregnancy.
Developmental Toxicant	Can cause harm to the developing child including birth defects, low birth weight, and biological or behavioral problems that appear over time.
Endocrine Disruptor	Can interfere with hormone communication between cells (the endocrine system), which controls metabolism, development, growth, reproduction, and behavior. Linked to health effects such as obesity, diabetes, male and female reproductive disorders, and altered brain development, among others.
Respiratory Sensitizer	Can result in high sensitivity such that small quantities trigger asthma, rhinitis, or other allergic reactions in the respiratory system. These compounds can exacerbate current asthma, and some have been shown to cause the disease itself.
Acutely Toxic Chemical	Can be fatal on contact, ingestion, or inhalation for humans and other mammals.
PBT (Persistent, Bioaccumulative Toxicant)	Persistent chemicals (P) do not break down readily from natural processes. Bioaccumulative chemicals (B) build up in organisms, concentrating as they move up the food chain. Toxic chemicals (T) are associated with one or more health hazards. Chemicals considered PBTs in this analysis are those listed on select authoritative hazard lists: the EPA's National Waste Minimization Program Priority PBTs or the European Union's European Chemical Substances Information System PBT List.[35]
Reactive Chemical	May spontaneously ignite or explode on its own or in contact with water.
Flammable Chemical	Can be easily ignited and is capable of burning rapidly.
Volatile Chemical	Volatility is an indication of how easily chemicals evaporate at normal temperature and pressure. For this case study, we use the European Union definition for determining whether an organic chemical is volatile. This definition is based on boiling point: Organic compounds with an initial boiling point below or equal to 250 °C at standard atmospheric pressure (101.3 kPa) are considered volatile organic compounds.[36] Because inorganic compounds that are volatile can also be hazardous and may also have increased potential for exposures when they are volatile, we use this boiling point cutoff to identify both organic and inorganic volatile compounds. Boiling point information was collected from REACH dossiers and ChemID Plus.[37]

Manufacturing Facilities and Surrounding Communities

Facility Locations

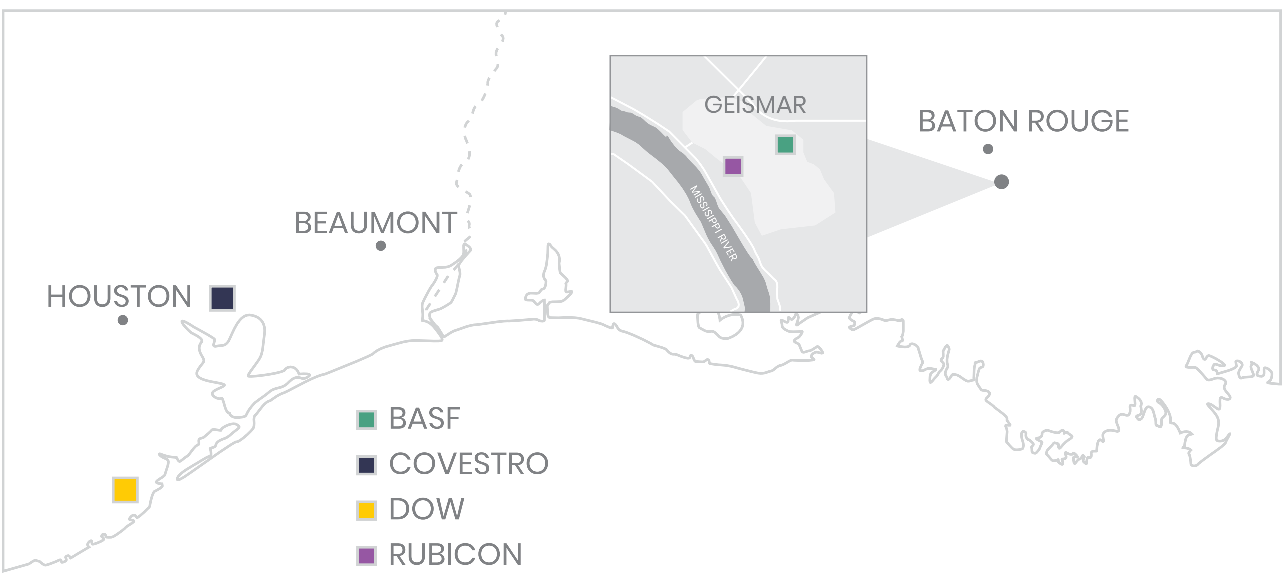
The EPA collects information on the production and importation of certain chemicals in the United States through Chemical Data Reporting (CDR).[38] Despite this, there is often a lack of public transparency, as much of the data collected is held as confidential business information. This is the case for MDI production capacities. Yet, publicly available information from other sources still allows the identification of major manufacturers and production capacity. The vast majority of MDI produced in the United States is made by four manufacturers: BASF, Covestro, Dow, and Rubicon, each with one facility. Two are in Texas, the others in Louisiana.[39] These facilities each have an estimated annual MDI production capacity of 300–450 metric kilotons (about 660 million to 1 billion pounds), and three of them are starting, continuing, or considering expansions to be completed in the next several years. See Table 4 and Figure 3 for details.[c,40]

Table 4. Major U.S. producers of MDI and approximate annual capacity

	Covestro	Dow	Rubicon	BASF
Location	Baytown, TX	Freeport, TX	Geismar, LA	Geismar, LA
Approximate MDI capacity (in millions of pounds)	704*	748	1,000*	660*

* Has announced or started projects to increase capacity.

FIGURE 3. Map of the major MDI manufacturing facilities in the United States. Inset shows BASF and Rubicon facilities in Geismar, Louisiana.



[c] For mapping throughout this case study, unless otherwise noted, facility locations are from EPA's Toxics Release Inventory and school locations are from EPA's EJScreen. Locations were mapped in Google Maps using latitude and longitude. For facilities not found in TRI, the street address was used. Report maps were generated in Illustrator based on the Google Maps. An interactive map with more exact locations is available here: https://www.google.com/maps/d/edit?mid=1XzI3fNSrhi6NJAGlVQafDGFiTNhrjLhK&usp=sharing

If we do not account for the effects of embodied chemicals, we won't understand the true impacts of materials on human and environmental health, and importantly, who is bearing the burden of these impacts.

Community Demographic Information
A fenceline community or frontline community is a neighborhood that is located near a chemical plant, industrial facility, or distribution center and is directly affected by the noise, odors, chemical emissions, heavy duty diesel emissions, and operations of the company.[41] To understand who is living in the fenceline communities surrounding these MDI manufacturing facilities, we completed a demographic analysis using the EPA's EJScreen tool.[42] We considered demographic characteristics related to marginalization and biological vulnerability. Marginalized communities "are those excluded from mainstream social, economic, educational, and/or cultural life. Examples of marginalized populations include, but are not limited to, groups excluded due to race, gender identity, sexual orientation, age, physical ability, language, and/or immigration status."[43] Marginalized groups have the highest burden of chronic diseases due to the inequitable distribution of harmful environmental and social factors.[44]

For the purposes of this analysis, we considered those living within a three-mile radius of a facility to be within the fenceline zone.[d,45] Table 5 provides summary information on race, ethnicity, low-income population, linguistically isolated population, population under age 18, and number of schools in fenceline zones for the four MDI manufacturing facilities and for the United States overall.

More on the EPA's EJScreen

Definitions:
Low-income population: The "population in households where the household income is less than or equal to twice the federal 'poverty level.' "

People of color: Individuals "who list their racial status as a race other than white alone and/or list their ethnicity as Hispanic or Latino."

Linguistically isolated population: People living in "a household in which all members age 14 years and over speak a non-English language and also speak English less than "very well" (have difficulty with English)."[46]

The EPA notes that there is "substantial uncertainty" in the demographic data, so this is intended as screening-level information.[47] For details on how EJScreen estimates demographics, see the EPA's EJScreen Technical Documentation.[48]

[d] For fenceline demographic analysis, facility location was determined using latitude and longitude reported in the EPA's Toxics Release Inventory (TRI) for each facility appearing in the inventory. For facilities not found in TRI, the street address was used. Note that some facilities are large, and using a three-mile radius from a single point may not adequately capture the full population within three miles of all edges of the facility. There is no single recognized definition of "fenceline community," and others living, working, or going to school outside the three-mile radius may also be impacted by chemical releases. Releases to the environment may travel different distances depending on many factors, including properties of the chemical itself, wind speed, temperature, and whether it is released to air or water. For example, risk management models show the potential scope of accidental releases ranging from less than one mile for a valve failure to more than 40 miles for a railcar failure.

Table 5. Demographic information for residents within three miles of each MDI manufacturing facility compared with the United States overall					
Facility and Location	**Rubicon Geismar, LA**	**BASF Geismar, LA**	**Dow Freeport, TX**	**Covestro Baytown, TX**	**U.S. Overall**
Population	1,463	1,462	13,220	23,889	322,903,030
	Percentage of Population				
Hispanic or Latino	5%	5%	60%	37%	18%
White Non-Hispanic	61%	62%	23%	49%	61%
Black or African-American	32%	31%	12%	11%	12%
American Indian or Alaska Native	0%	0%	3%	0%	0.7%
Asian	2%	2%	1%	1%	5%
Native Hawaiian or Other Pacific Islander	0%	0%	0%	0%	0.2%
Other Race	0%	0%	0%	0%	0.2%
Two or More Races	0.3%	0.3%	2%	2%	2%
People of Color	39%	38%	77%	51%	39%
Low Income	20%	17%	58%	29%	33%
Linguistically Isolated	2%	2%	7%	6%	4%
Under 18 Years Old	30%	30%	34%	29%	23%
Number of Schools	0	0	6	4	

Orange highlights indicate where the percentage of historically marginalized populations in the fenceline zone is greater than in the nation as a whole. The ACS reports both on race (white, Black, Asian, American Indian or Alaska Native, Native Hawaiian or other Pacific Islander, other race, or two or more races) and on ethnicity (Hispanic or Latino). Hispanic or Latino individuals will also fall into one or more of the race categories. To avoid double-counting individuals, this table includes individuals reporting Hispanic or Latino in the row for Hispanic or Latino. Individuals reporting non-Hispanic or Latino are included in the subsequent rows. *Sources: EPA's EJScreen and U.S. Census Bureau American Community Survey five-year estimates for 2014–2018.*[49]

All four facilities are sited in places that are disproportionately Black, Latino, and/or American Indian/Alaska Native. The proportions of Black residents in the fenceline zones around the Louisiana facilities (Rubicon and BASF) are more than 2.5 times the proportion of Black residents in the U.S. overall. The percentages of Latinos and American Indian/Alaska Natives living near the Dow facility are both three times the percentages in the United States overall, and the percentage of Latinos around Covestro is twice that of the nation overall. Some of the fenceline communities have multiple vulnerabilities, such as disproportionately having low incomes and being linguistically isolated.

Children are a high percentage of the population in proximity to the four facilities—29 to 34 percent, compared with 23 percent in the U.S. population overall. This is a particular concern when hazardous chemicals are released; while we are all impacted by chemical exposures, children are biologically vulnerable—they are affected more than adults due to their smaller size and their still-developing bodies.[50] Two of the facilities (Dow and Covestro) also have several schools located in close proximity, so school-age children may be exposed to hazardous releases both where they live and where they learn (Figure 4). The Rubicon and BASF facilities are located within about a mile of each other, so local residents may be impacted by both facilities.

The four facilities are located in two states, and there can be significant regional variations in demographics among states and locales. Comparing fenceline zone demographics with more localized data can highlight disparities in addition to those observed on a national

FIGURE 4. Location of Dow facility in Freeport, Texas, and of six schools within a three-mile radius.

Source: EPA's EJScreen

level. For example, the percentage of people of color in the fenceline zone for the Dow facility is not only higher than in the nation overall, but also significantly higher than within Texas, where the facility is located. See Appendix 2 for more information.

We also compared the combined demographics of the fenceline communities for these four facilities with those of the United States overall to get a broader understanding of who is impacted by MDI manufacturing. Because Rubicon and BASF are so close together, some individuals are included in both fenceline zones; therefore the following information is approximate. Around 40,000 people live in the combined fenceline zones, about 30 percent of whom are children. Nearly 60 percent of the combined population are people of color. The percentage of Latinos living in the combined zones is more than double that of Latinos in the nation overall. Low-income and linguistically isolated populations are also proportionally greater in the combined fenceline zones than in the nation overall.

Manufacturing Releases, Waste, Pollution Prevention, and Compliance

During the MDI manufacturing process, facilities use and generate hazardous chemicals that may be emitted to air or discharged to water (i.e., released), or collected for recycling or waste disposal. For some of these chemicals, facilities must annually report the quantities that are released, recycled, or disposed of to the EPA through the Toxics Release Inventory (TRI) program.[51] Almost all of the primary chemicals and intermediates used in MDI manufacture require reporting through TRI because of their associated hazards (see Table 2). Isocyanates are not reported individually, but some are reported as part of the diisocyanates chemical category.[e,52] The program also collects and records pollution prevention activities to identify effective environmental practices and highlight successes in reducing pollution.[53] TRI data are publicly available and were used for the following analysis.

[e] Diisocyanates reporting includes 20 different CASRNs, including PMDI (CAS 9016-87-9) and MDI (CAS 101-68-8). Other diisocyanates that may be included in the mixture used in spray foam insulation (e.g., CAS 5873-54-1 and 26447-40-5) are not included in the diisocyanates TRI reporting.

Compliance with EPA regulations is also publicly reported for facilities and is discussed below as well. The amounts of hazardous chemical releases and waste, actions taken to reduce pollution, and whether a facility is in compliance with environmental regulations all contribute to the impacts these facilities have on neighboring communities and the broader environment.

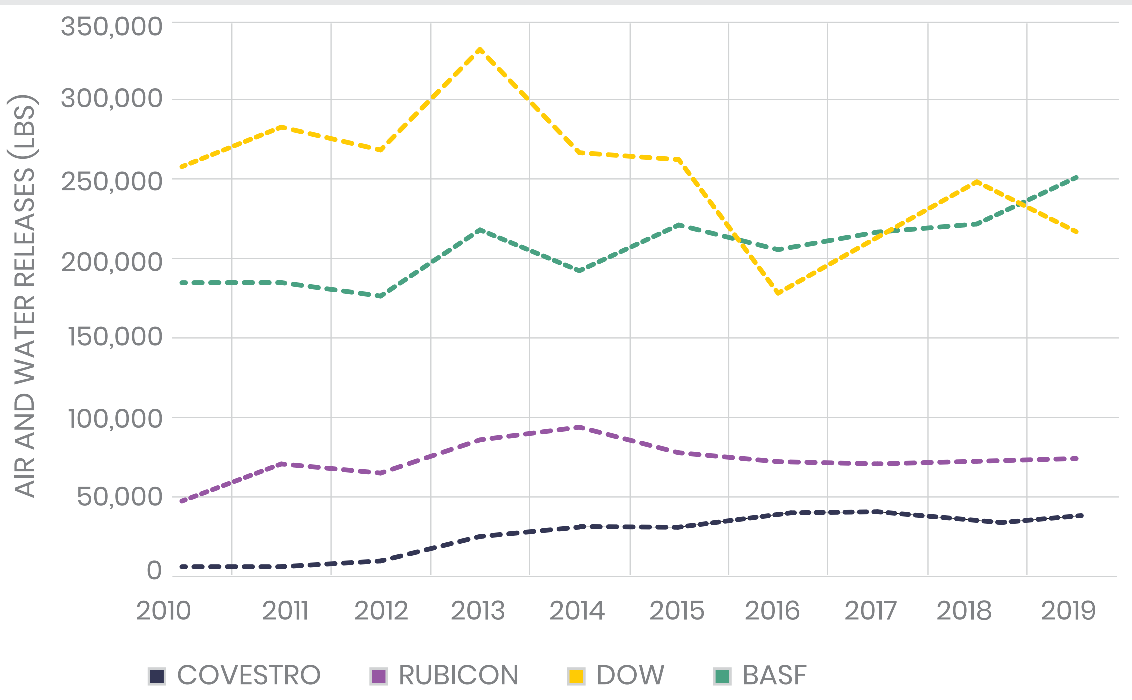
Releases to Air and Water

We analyzed the air and water releases reported by the four MDI manufacturing facilities identified in Table 3. Because these facilities produce other things in addition to MDI, their TRI reporting may include releases attributable to these other processes. To focus on impacts tied to MDI production specifically, we analyzed only those chemicals that are known to be part of MDI manufacturing—those listed in Table 2.

There are several limitations to this approach. First, it may not eliminate all the releases associated with other manufacturing processes at the facility. Second, TRI reporting requirements do not include all toxic chemicals used in the United States—for instance, some variations of MDI are excluded—and chemicals must be reported only when they are released above established thresholds. Consequently, there may be additional releases attributable to MDI manufacturing that are not included in our analysis. Also, releases are not directly comparable across facilities in terms of pollution per a given output of MDI production. This is because some facilities may not perform all steps of the manufacturing process on site, some conduct other manufacturing processes that may use the same chemicals, and each facility has a different MDI production capacity. However, greater amounts of hazardous releases, regardless of these other factors, can still translate to greater overall impacts on surrounding communities and the environment. Finally, since releases are self-reported by facilities, there may also be variations in how different manufacturers account for and report releases.

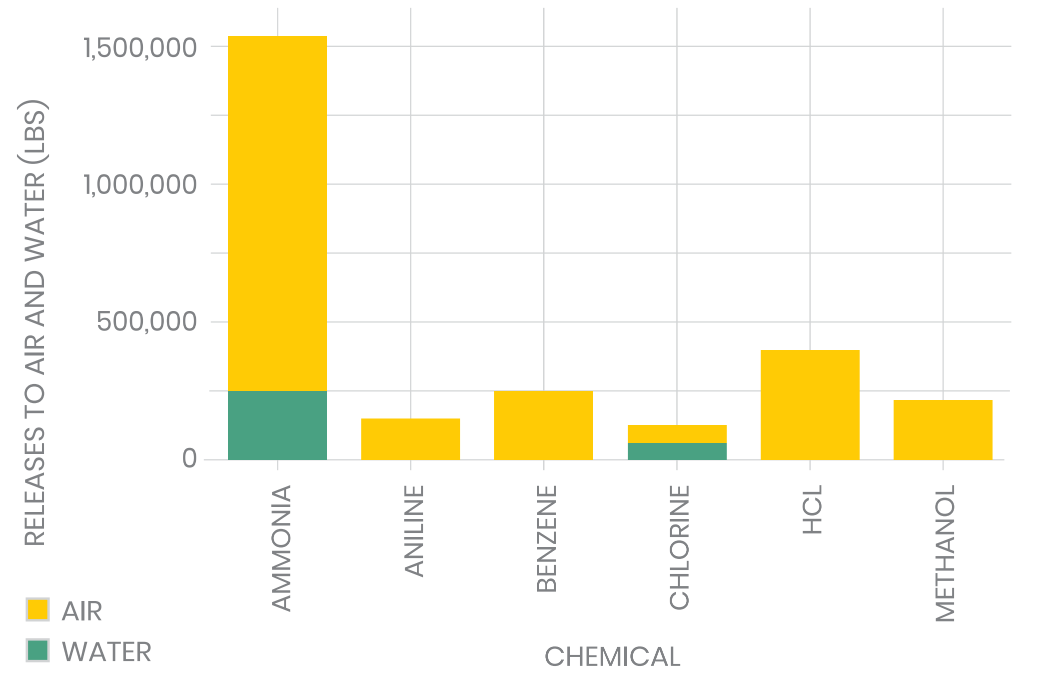
The analysis in this section is focused on the production of MDI, but communities are also impacted by releases of hazardous chemicals related to other activity at the same facilities. We consider this in the “Communities and Cumulative Impacts” section below.

FIGURE 5. Combined air and water releases for 12 MDI-related chemicals or chemical groups (MDA, ammonia, aniline, benzene, chlorine, diisocyanates, formaldehyde, methanol, nitric acid, nitrobenzene, phosgene, and hydrochloric acid) reported to the EPA (2010–2019). Release amounts are not directly comparable between facilities (see text).



Source: EPA Toxics Release Inventory.

FIGURE 6. Total releases of MDI–related chemicals to air and water for all four facilities, 2015–2019. The chemicals with the highest releases are included.



Source: EPA Toxics Release Inventory.

All the TRI-reportable chemicals used in MDI production had releases at one or more of the studied facilities over the last five years. The total air and water releases of MDI-related chemicals from each facility each year are shown in Figure 5. The chemicals and quantities of those chemicals released vary among facilities and from year to year, but there does not appear to be a particular trend (increasing or decreasing) over time. Both the Dow and BASF facilities reported total releases of these chemicals of around 200,000 pounds or more each year. These facilities manufacture a range of other chemicals, which may contribute to their higher releases of the chemicals of interest. From 2015 to 2019, the four facilities released to air and water a collective average of 560,000 pounds/year of the chemicals of interest.

Figure 6 shows the MDI-related chemicals with the highest releases over a five-year period for all four facilities combined. The respiratory sensitizer ammonia was by far the highest, with more than 1.5 million pounds released to the air and water surrounding the four MDI facilities between 2015 and 2019. After ammonia, the next-largest releases to the air were aniline, benzene, chlorine, hydrochloric acid, and methanol. The next-largest release to water was chlorine.

Waste

The manufacture of MDI generates hazardous chemical waste.[f] Chemicals released on site to the air and water, discussed in the previous section, are considered waste because they are not used for their intended purpose. Waste reported through TRI also includes chemicals released to land (e.g., to landfills), recycled, or otherwise disposed of either on or off site. Figure 6 highlights air and water releases specifically because there is a greater potential for exposure from these releases than from other on-site waste management practices, but all hazardous chemical waste can result in exposures and is an indication of inefficiencies within the system.

Releases and disposal of TRI-reportable chemicals must be disclosed to the EPA along with the type of release or disposal method. Disposal methods include landfill, injection into underground wells, energy recovery, and treatment.[54] *Energy recovery* means that the chemical is burned to generate heat or energy for use at the

[f] *Hazardous waste* is legally defined by the Resource Conservation and Recovery Act (RCRA). We use the phrase “hazardous chemical waste” to mean hazardous chemicals that are disposed of as waste. Some hazardous chemical wastes may meet the legal definition of “hazardous waste”; others may not.

facility.[55] *Treatment* often means incineration, though it can include other methods meant to destroy the toxic chemical.[56] Burning of hazardous chemicals can lead to additional hazardous releases.[57] All four facilities report on-site treatment and/or energy recovery for large quantities of MDI–related waste chemicals.

The following analysis is based on waste data reported through TRI for the MDI–related chemicals in Table 2. Some of this waste may be attributed to other processes.

Figure 7 shows the average annual waste that was recycled, disposed of off site, or released or disposed of on site from 2015 through 2019 for all the facilities combined. During this time period, a small percentage of the MDI–related waste was recycled on or off site. Chemicals reported as recycled were excluded from the rest of this analysis, although some material sent for recycling may also end up as waste.

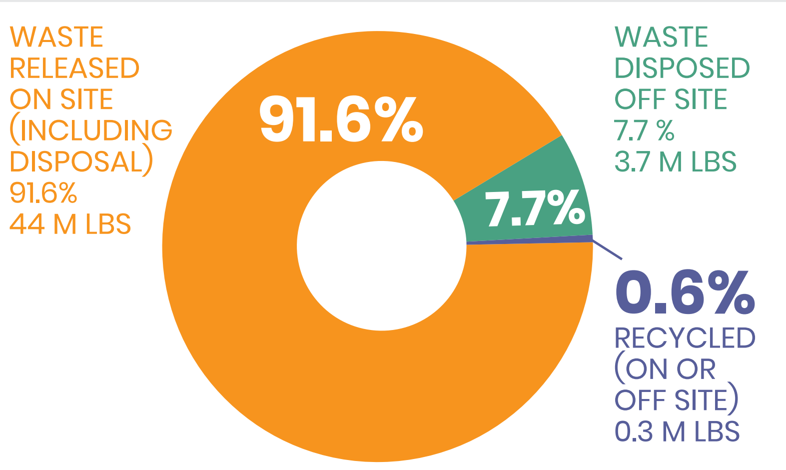
From 2015 through 2019, the four facilities collectively released or disposed of more than 47.7 million pounds of MDI–related chemicals every year, on average. Of this, an average of 44 million pounds per year was released or disposed of on site; the remainder was transferred off site. For BASF, Dow, and Rubicon, most of the MDI–related chemical waste was disposed of on site, whereas Covestro transferred most of its waste off site for disposal. All four facilities reported transfers of MDI-related chemicals to waste facilities. See the "Tracing the Supply Chain" section for more information on off-site transfers. See Appendix 3 for facility-specific waste information.

Rubicon was the only facility to report disposal in on-site injection wells, where waste is sent deep into the earth in confined rock formations.[58] Rubicon's reported injection well disposals consisted primarily of MDA, ammonia, aniline, methanol, and nitrobenzene and were significant in quantity, amounting to 7 million pounds in 2019 alone. The amount of waste that Rubicon disposed of via injection well increased dramatically over the past several years, nearly doubling from 2014 to 2019. While this disposal method is meant to hold the chemicals in place, unforeseen leakage and contamination of groundwater and drinking water are possible, making the scale of injection well disposal at the Rubicon facility particularly concerning.[59] Another concern with injection wells is that they can cause seismic instability and lead to earthquakes.[60]

Pollution Prevention

Under the TRI program, the EPA also collects information on pollution prevention measures reported by facilities.[61] Rubicon, for example, reported that several such measures were implemented in 2018 and 2019, including modification of equipment, layout, or piping to reduce releases of chlorine, MDA, and nitrobenzene. (It should be noted, though, that the total releases of chemicals of interest to air and water went up slightly in that time frame for this facility). The Covestro facility last reported pollution reduction efforts for any chemical in 2015, and Dow in 2005; none were listed for BASF in the TRI database.

FIGURE 7. Average annual MDI–related chemicals recycled, disposed of off site, and released on site (including disposal) for all four facilities, 2015–2019.



Source: EPA Toxics Release Inventory.

Table 6. Facilities with significant violations of EPA regulations for the most recent 12 quarters as of May 2021[64]		
Manufacturer	Location	Number of Quarters With Significant Violations
Rubicon	Geismar, LA	0 of 12
BASF	Geismar, LA	8 of 12
Covestro	Baytown, TX	12 of 12
Dow	Freeport, TX	12 of 12

Compliance

The EPA reports data on facility compliance with environmental regulations related to clean air, clean water, and hazardous waste for the most recent 12 quarters (3 years).[g,62] The MDI manufacturing facilities show a history of noncompliance as of May 2021 (Table 6). Rubicon was in noncompliance for 2 of the last 12 quarters but had no significant violations.[63] EPA regulations can help protect communities, workers, and the environment from dangerous pollution and chemicals; although these violations may or may not be related to MDI production specifically, they suggest a concerning pattern at these facilities of disregarding important safeguards.

Worker and Fenceline Community Impacts

Facilities' use, release, and disposal of hazardous chemicals affect both workers and communities. Releases occur during regular manufacturing as well as during nonroutine events such as equipment failures or weather-related incidents. These events can lead to even higher levels of exposure for workers and communities and disrupt daily life for residents. The next sections consider some of the impacts of releases on workers and fenceline communities tied to MDI manufacturing.

Workers

Hazardous chemicals in manufacturing can expose workers on the job. As noted above, MDI itself has been a leading cause of work-related asthma. Exposure to MDI both through inhalation and through skin contact is thought to contribute to the development of the disease.[65] The EPA notes that skin exposure to MDI may occur even when workers are wearing protective equipment.[66]

Exposures to chemicals used in the manufacturing process may occur in the course of routine activities like charging reactor vessels, bulk loading of chemicals, cleaning of equipment, and maintenance, or as the result of an accident.[67] Personal protective equipment and engineering controls like ventilation may be employed to reduce worker exposures; however, each of these measures can fail through user error or malfunction. Eliminating the use of hazardous chemicals is the most effective means of protection.[68]

Several incidents resulting in worker exposures at MDI facilities are documented. For example, OSHA reports that in 2017, a worker at the Covestro facility in Texas was hospitalized with chemical burns after being sprayed with liquid chlorine.[69] In 2021, a local newspaper reported on 25 incidents with hazardous chemicals at the Rubicon facility over the past decade that led to the exposure or potential exposure of a total of 130 workers, of whom 22 required off-site treatment. One such incident involved a worker who was exposed to aniline, which blocked his uptake of oxygen—a life-threatening situation that required hospitalization.[70]

Communities and Cumulative Impacts

Consistent releases of hazardous chemicals to air and water and on-site waste disposal, as discussed above, can all impact communities near MDI facilities. In addition, nonroutine events can lead to additional releases and exposures. For example, three releases of phosgene from the Rubicon facility between 2016 and 2020 required community shelter-in-place

[g] These regulations include the Clean Air Act, Clean Water Act, and Resource Conservation and Recovery Act. Noncompliance can only be discovered by EPA inspections and enforcement, but the EPA lacks resources to conduct these activities and cannot inspect all facilities. Therefore, quarters without violations may simply reflect lack of inspection and do not necessarily mean a facility is in compliance. When violations are identified, they may be corrected by the facility without formal enforcement action; more serious or continuing violations may result in formal administrative orders, fines, or judicial cases.

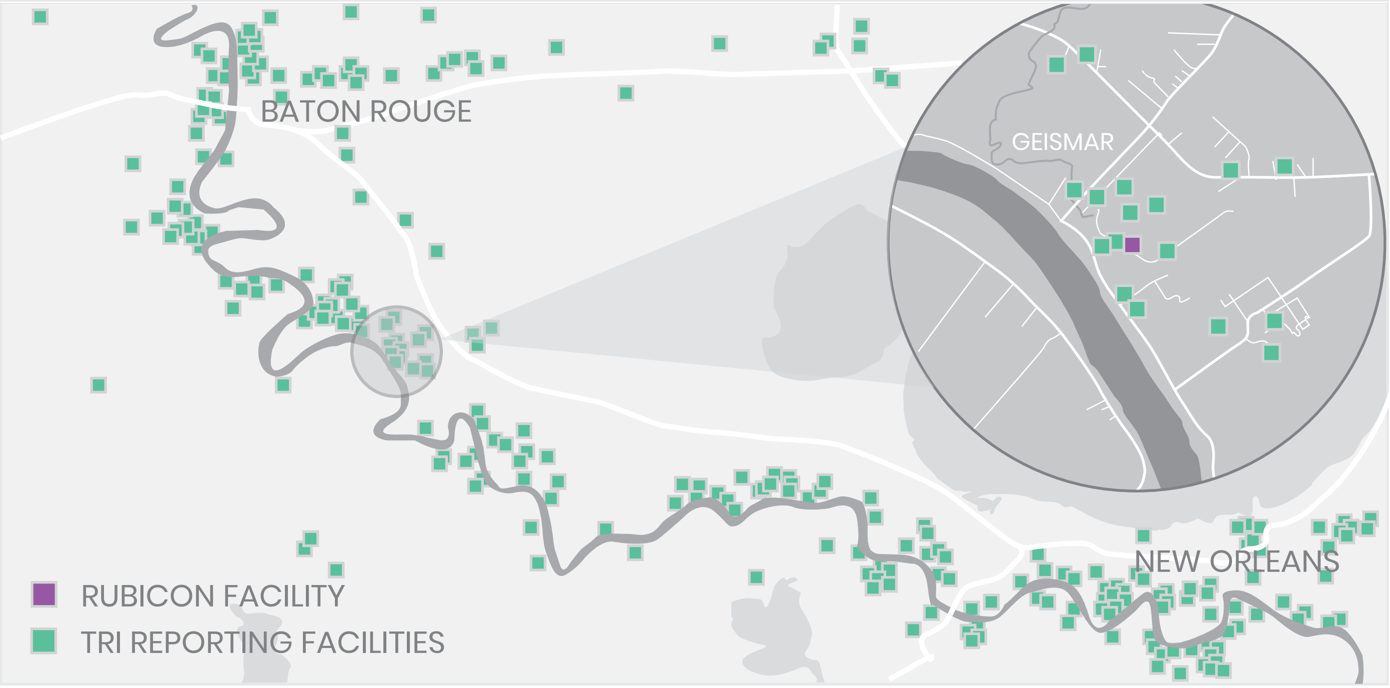
orders.[71] Severe weather events like hurricanes, extreme temperatures, and flooding, as well as the power outages and damage caused by storms, can lead to releases and fires that are dangerous for communities and first responders.[72] Houston-area facilities reported planned releases of more than 4 million pounds of pollution as they shut down ahead of Hurricane Laura's landfall in 2020.[73] The Covestro plant reported a release of more than 3,000 pounds of ammonia due to a valve malfunction associated with the extremely low temperatures experienced in Texas in February 2021.[74]

While the impacts of specific processes and facilities discussed above are important to consider, it is also imperative to understand the total, cumulative impacts experienced by communities near MDI plants—that is, the total harm resulting from a combination of stressors over time. U.S. policies have largely failed to evaluate, mitigate, or prevent cumulative impacts. In the United States, communities of color and low-income communities are disproportionately affected by environmental pollutants.[75] They often face hazards from multiple sources due to high concentrations of industrial facilities, contaminated sites, traffic, and other sources of pollutants near their homes. At the same time, these communities disproportionately experience other stressors tied to poor health outcomes, such as poverty, lack of access to adequate health care, racial discrimination, and additional factors related to the social determinants of health.[76] A community experiencing cumulative impacts may be identified as an overburdened, disadvantaged, and/or an environmental justice community in local, state, or federal policies. For example, New Jersey state law defines an overburdened community as a census block group in which a certain percentage of households are low income or have limited English proficiency, or a certain percentage of residents are minority or tribal members.[77]

The risk-based regulatory system generally considers one chemical at a time, or one facility at a time, in isolation from the real-world context in which it exists—such as in proximity to many other sources of hazardous pollutants. This approach fails to prevent the accumulation of substantial harms to communities.[78]

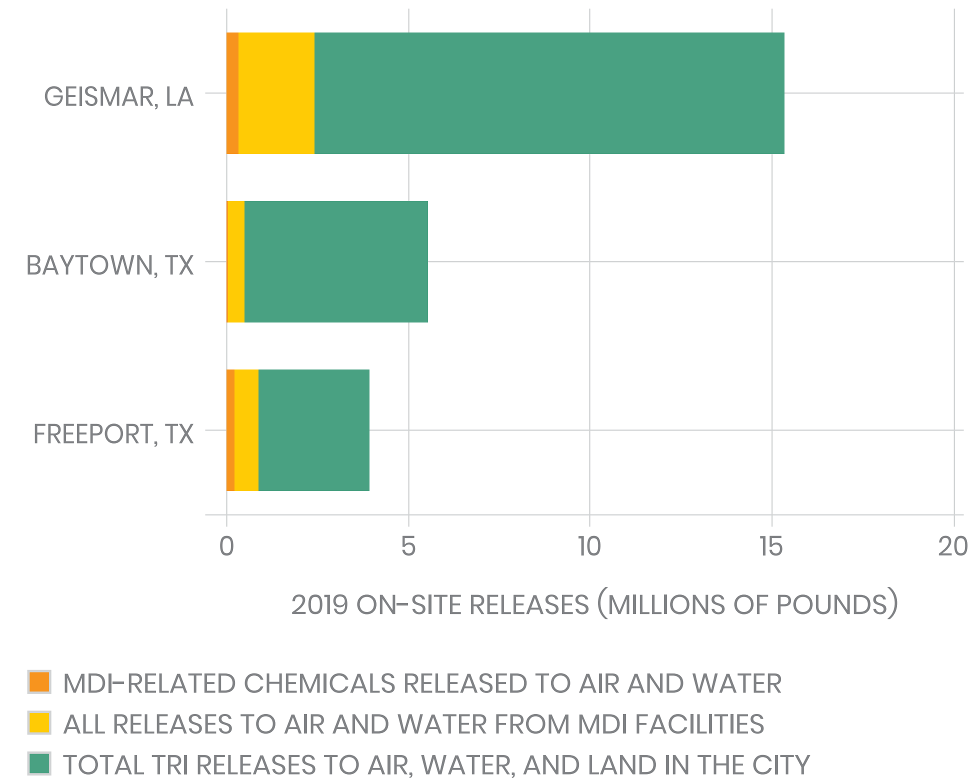
In the following analysis, we consider additional environmental releases not related to MDI that affect the communities surrounding the MDI manufacturing facilities to provide some information on cumulative impacts. However, we did not conduct a comprehensive

FIGURE 8. Map of TRI-reporting facilities along the Mississippi River between New Orleans and Baton Rouge in the area known as "Death Alley." The circle indicates a three-mile radius around the Rubicon facility in Geismar, including the 18 TRI facilities in the town itself.



Source: EPA EJScreen

FIGURE 9. MDI–related releases to air and water, all releases from MDI facilities to air and water, and all releases in the cities where MDI is produced.



Source: EPA Toxics Release Inventory.

analysis of the many other stressors that cumulatively impact community health.

First, the MDI manufacturing facilities themselves release hazardous chemicals from other processes performed there. All four facilities release additional TRI-reportable chemicals at significant quantities, with total TRI releases ranging from 328,000 pounds to more than 2 million pounds in 2019 (see Appendix 3 for more details). Second, there are releases from other facilities located in these communities, contributing to the overall environmental and health impacts for residents.

Geismar is part of the area along the Mississippi River between New Orleans and Baton Rouge known as "Death Alley" because of the concentration of industrial activity and the associated elevated cancer risks.[79] Figure 8 maps the TRI-reporting facilities in this area, including the 18 TRI facilities in the town of Geismar.

Not only Geismar but also Freeport and Baytown in Texas have a large number of TRI-reporting facilities (see Appendix 3 for more details). These facilities release dozens of chemicals that the EPA identifies as known or suspected carcinogens, such as ethylene oxide, 1,2-dichloroethane, and 1,3 butadiene, in addition to the benzene, nitrobenzene, formaldehyde, and MDA that are used in MDI manufacturing. Each of these cities sees millions of pounds of hazardous chemical releases to the air, water, and land every year. Figure 9 shows the reported releases to the air and water of MDI–related chemicals and all TRI-reportable chemicals from MDI facilities, as well as the total releases reported for TRI facilities in each city considered in this case study.

TRI data for the last 10 years show an upward trend in the combined quantity of on-site releases reported in Geismar. There is no clear trend in total on-site releases over time in Freeport or Baytown, but the 2019 releases in Baytown were significantly higher than in previous years, which may be indicative of a future trend.

TRACING THE SUPPLY CHAIN

Chemical impacts can occur throughout the MDI and SPF manufacturing supply chains. MDI inputs are petroleum-based, and though not the focus of this study, oil and gas extraction and processing have significant impacts on surrounding communities.[80] The chemicals used to make MDI may be manufactured on site or brought in from other factories. Hazardous chemical waste generated in this process can be disposed of on site or transferred to incinerators or landfills. Once manufactured, the MDI may be used within the same operation to produce SPF, or it may be sold to another spray foam manufacturer or a manufacturer of different types of products. At each of these stages of the supply chain, releases and impacts on surrounding communities are possible. In general, the lack of transparency and traceability within supply chains precludes a full understanding of these impacts. Below, we provide examples tracing the movements of an input material and of waste, focusing on the MDI manufacturing facilities located in Louisiana.

Feedstock for MDI Manufacture

Chlorine is needed to make a key chemical required for MDI manufacturing (Figure 2). BASF and Rubicon receive liquid chlorine via a pipeline from the Occidental Chemical facility in Geismar and from the Olin facility in St. Gabriel, Louisiana.[81] Chlorine manufacturing can impact communities. For example, prior to 2009, the St. Gabriel facility used mercury in its chlorine production. In 2005, the Natural Resources Defense Council (NRDC) tested air near the St. Gabriel plant and found mercury concentrations as high as 2,629 ng/m^3 (nanograms per cubic meter), nearly 10 times the EPA's "safe level" for chronic mercury exposure, 300 ng/m^3.[82] Both the Occidental and Olin facilities now use PFAS-based diaphragm or membrane technology to manufacture

Chlorine Manufacture

In isocyanate manufacturing, chlorine is needed to synthesize the intermediate phosgene. Taking the chemical considerations for MDI back another step, chlorine gas is produced by four technologies, each with hazardous chemical concerns. Older technologies utilize mercury cells and asbestos diaphragms to break sodium chloride into chlorine and sodium hydroxide. Newer technologies use either PFAS diaphragms or PFAS-coated membranes. While most chlorine production has transitioned to the latter two technologies, all four methods of production are still used.[84] Each production technology has tradeoffs from a chemical hazard perspective. Mercury and asbestos have a range of health hazards and impacts throughout their supply chains. PFAS chemicals can be persistent, bioaccumulative, and toxic.[85] The production of PFAS chemicals used in chlorine manufacture has led to releases of PFAS into the environment and ultimately into people. For example, 99 percent of adults and 100 percent of children tested living downriver from a manufacturing facility in Wilmington, North Carolina, had detectable PFAS levels in their blood.[86] Chlorine manufacture is also associated with the release of various hazardous chlorinated compounds into the environment.[87] Additional data related to chlorine production are available through the Chlorine & Building Materials Project.[88]

chlorine, which has its own life cycle concerns.[83] See the "Chlorine Manufacture" text box for more information.

In December 2014, a local TV station reported that three people had been taken to the hospital for exposure to chlorine released from a storage tank at the St. Gabriel facility and that a yellow cloud had been seen over the plant.[89] In July 2017, a chlorine leak was reported at the same plant. This time, 11 employees were treated for injuries on site. The police blocked traffic two miles from the plant, and nearby residents were told to stay inside, shut all doors and windows, and turn off air-conditioning or heating units and attic fans (note that the average high temperature in St. Gabriel in July is 91 degrees F).[90]

Releases from these chlorine manufacturing facilities have environmental justice impacts. The fenceline zones for the Occidental and Olin facilities have a much greater percentage of Black residents than the United States overall—43 percent of the population surrounding Occidental and 68 percent of the population surrounding Olin, compared with 12 percent nationally. Fifty percent of the fenceline community around Olin is low income, compared with 33 percent in the United States overall. Additionally, three schools are located within three miles of the Olin facility (Table 7).

From MDI Manufacturing to SPF Manufacturing

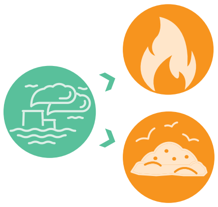
MDI made at the facilities considered in this case study may travel to other plants for further processing, which can impact other communities as part of the SPF supply chain. This is currently the case for Dow, which distills MDI at a facility in La Porte, Texas. In 2021 Dow announced plans to move this part of the process to its Freeport location and close down this capacity in La Porte.[91] In other cases, the MDI component of SPF insulation may be fully processed at the same location.[92] These materials are then sent to SPF manufacturers.

Rubicon and BASF are also SPF manufacturers. The Rubicon facility is a joint venture with the global chemicals company Huntsman, which also manufactures spray foam insulation, likely using MDI manufactured at Rubicon.[93] Huntsman acquired the spray foam manufacturers Demilec in 2018 and Icynene-Lapolla in 2020, creating the world's largest supplier of spray foam insulation for commercial and residential buildings.[94] In the United States, Huntsman manufactures SPF in Arlington, Texas (at the former

[h] In this case, TRI reporting would be required if there are more than 10 full-time employees at the facility and TRI-reportable chemicals are manufactured, processed, or otherwise used in excess of the reporting threshold. For most chemicals, the threshold is 25,000 pounds manufactured or processed in the calendar year. If MDI is not processed or repackaged at these facilities, it would not need to be reported. Given the contents of Demilec and Icynene-Lapolla products, it is thought that ethylene glycol, a TRI-reportable chemical, may be processed at these facilities in blending of the B-side component, but the quantity may be below the reporting threshold.

Demilec site) and in Houston (at the former Icynene-Lapolla site).[95] There were no reported TRI releases from these facilities.[h,96]

BASF manufactures spray foam insulation as well. MDI made at the BASF facility is likely used in the company's spray foam manufacturing in Houston and in Orange, California.[97] These two facilities are found in the TRI reporting database, which reports that diisocyanates are used at these locations. The Houston facility reports that less than 500 pounds of diisocyanate are released per year and that less than 1 million pounds of diisocyanates are processed or otherwise used annually. It reported 750 pounds of non-production releases of diisocyanates (associated with remedial actions, catastrophic events, or other one-time events) in 2007. The Orange facility does not report on-site isocyanate releases. It has, however, reported large off-site transfers of diisocyanates for incineration at Clean Harbors in La Porte—96,000 pounds in 2019.



Waste Transfers From MDI and SPF Manufacturing

All four MDI manufacturing facilities report transfers of MDI–related chemicals for incineration at waste facilities from Texas to Arkansas to Mississippi. Some chemical waste is also sent to hazardous waste landfills in Louisiana or Oklahoma. When hazardous chemicals are transported and disposed of, additional releases are possible, and communities in proximity to incinerators and landfills are impacted.[98]

As an example, all four MDI facilities send hazardous chemical waste to the Clean Harbors incineration facility in La Porte. Covestro transferred more than

Table 7. Summary of demographic information for residents within three-mile radius of example facilities that are part of the MDI life cycle, compared with the United States overall

Facility and Location	Occidental Geismar, LA	Olin St. Gabriel, LA	Clean Harbors La Porte, TX	U.S. Overall
Function in Supply Chain	Chlorine Manufacturing	Chlorine Manufacturing	Waste Incineration	
	Fenceline Communities			
Population	2,261	4,681	9,028	322,903,030
	Percentage of Population			
Hispanic or Latino	3%	1%	29%	18%
White Non-Hispanic	51%	29%	66%	61%
Black or African American	43%	68%	0.3%	12%
American Indian or Alaska Native	0%	0%	0.8%	0.7%
Asian	1%	0%	2%	5%
Native Hawaiian or Other Pacific Islander	0%	0%	0%	0.2%
Other Race	0.4%	0%	0%	0.2%
Two or More Races	2%	1%	1%	2%
People of Color	49%	71%	34%	39%
Low Income	29%	50%	17%	33%
Linguistically Isolated	0%	0%	0%	4%
Number of Schools	0	3	4	

Orange highlights indicate percentages of historically marginalized populations that exceed national figures. The ACS reports both on race (white, Black, Asian, American Indian or Alaska Native, Native Hawaiian or other Pacific Islander, other race, or two or more races) and on ethnicity (Hispanic or Latino). Hispanic or Latino individuals will also fall into one or more of the race categories. To avoid double-counting individuals, this table includes individuals reporting Hispanic or Latino in the row for Hispanic or Latino. Individuals reporting non-Hispanic or Latino are included in the subsequent rows.

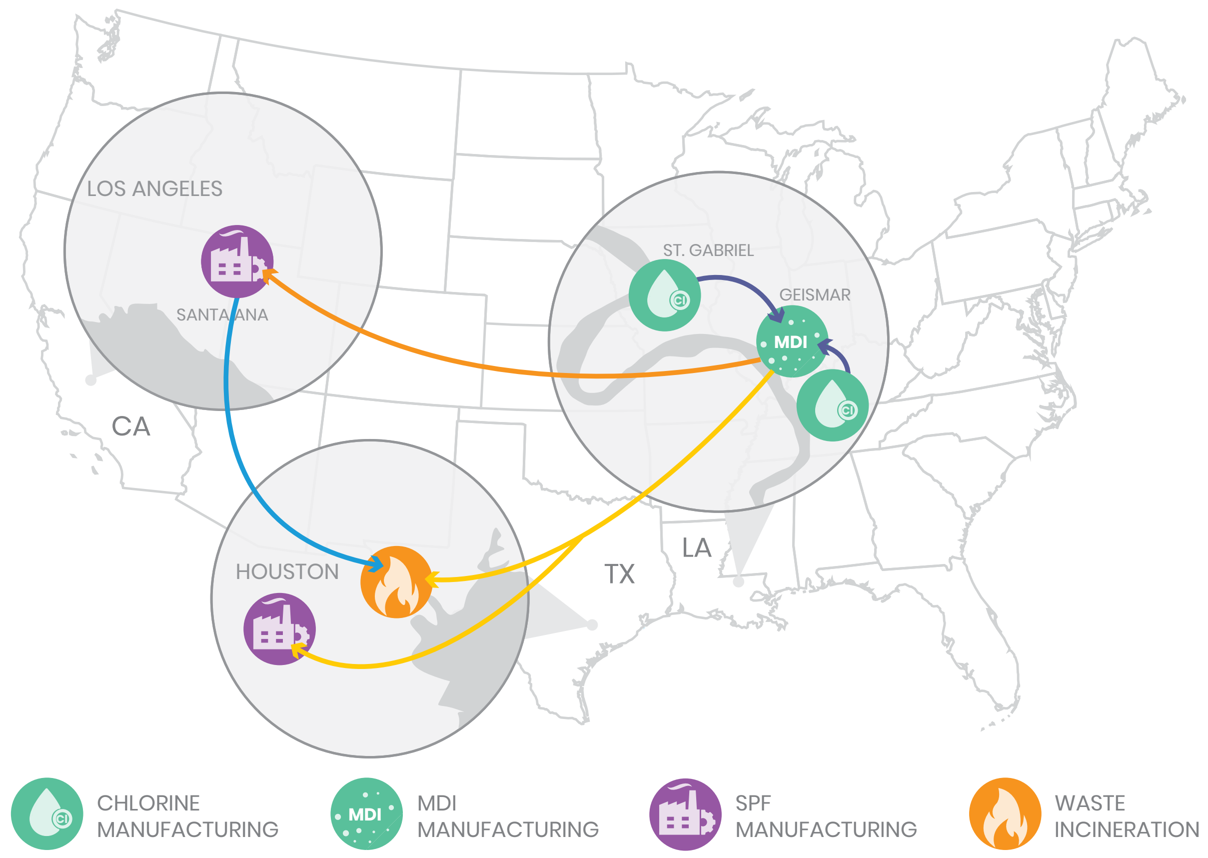
Sources: EPA's EJScreen and U.S. Census Bureau American Community Survey five-year estimates for 2014–2018.[99]

37,000 pounds of MDA, more than 190,000 pounds of aniline, and almost 687,000 pounds of diisocyanates to this incineration facility in 2019. This same facility received diisocyanates from BASF, as noted above. The community surrounding this incineration facility has a larger percentage of Latino residents than in the nation overall (see Table 7). Four schools were identified within three miles of this facility.

Figure 10 illustrates an example of how hazardous chemicals move throughout the supply chain for MDI and SPF.

When hazardous chemicals are transported and disposed of, additional releases are possible, and communities in proximity to incinerators and landfills are impacted.

FIGURE 10. Example movement of chemicals within the MDI supply chain. Chlorine travels from Occidental (Geismar, LA) and Olin (St. Gabriel, LA) to the BASF MDI facility in Geismar, LA; waste chemicals from the MDI facility travel to Clean Harbors in La Porte, TX for incineration; MDI from Geismar goes to BASF SPF manufacturing in Orange, CA and Houston, TX; and waste chemicals from the Orange, CA spray foam manufacturing facility travel to Clean Harbors for incineration.



Installation and Use Phase

While this case study is focused on chemical impacts outside the use phase, chemical hazards and impacts also occur during installation and use. Because SPF reacts on site as it is installed, there is the potential for workers and anyone else who may be present during and following installation to be exposed to hazardous chemicals including MDI. Respiratory sensitization impacts from MDI can come both from inhaling vapors and from skin contact with the chemicals.[100] Other hazardous chemicals used in spray foam insulation, including the halogenated flame retardant TCPP, a suspected carcinogen, pose additional concern during installation and over time.[101]

For additional information on a range of chemicals used in spray foam insulation, their associated health hazards, and potential impacts during installation and use, see “Making Affordable Multifamily Housing More Energy Efficient: A Guide to Healthier Upgrade Materials.”[102]

END OF LIFE OF SPRAY FOAM INSULATION

End-of-Life Scenarios

Spray foam insulation products are intended to last the lifetime of a building, or about 75 years. At the end of life or end of use, SPF is typically collected as mixed construction waste and landfilled.[103] Since unreacted MDI is not expected to be present at this point, releases of MDI are unlikely at the end of life for SPF, but other hazardous chemicals such as halogenated flame retardants and blowing agents may be released. In addition, fires in landfills, or any other uncontrolled burning of halogenated flame retardants like those found in SPF, may produce highly hazardous chemicals such as halogenated dioxins and furans.[104]

Further, small plastic particles (often referred to as microplastics) are generated when foam insulation is cut or sanded during installation, during building demolition, or if the material is ground for recycling.[105] These particles can then enter the environment. Microplastics from polyurethanes have been found in oceans and municipal water influent.[106]

Spray foam insulation is unlikely to be reused now or in the future. Because it is foamed in place, it assumes irregular shapes that limit how the material could be reused. In addition, SPF adheres to the materials around it, making it difficult to separate the SPF or reuse or recycle the surrounding materials, such as wood studs. No formal SPF recycling programs currently exist in the United States.

Though not common, some SPF insulation may be incinerated as part of municipal solid waste. Municipal waste incinerators have been associated with hazardous releases and adverse health impacts on surrounding communities.[107] Modern incinerators have equipment to capture some toxic pollutants that are generated, but this is effective only if the facilities are regularly maintained and operating properly.[108]

Building Fires

Building fires also occur. In extreme cases, excessive heat release during installation of SPF has led to fires.[109] Plastic insulation materials like SPF release toxic chemicals during combustion.[110] These combustion by-products can produce dangerous conditions for residents.[111] The fires can also contribute to firefighters' exposure to hazardous chemicals such as isocyanates, MDA, hydrogen cyanide, and others.[112] The flame retardants, dioxins, and furans found in fire smoke may come from a range of sources within a fire, but foam insulation with halogenated flame retardants likely contributes to these firefighter exposures.[113] Such exposures during and after firefighting may contribute to firefighters' increased risk of developing certain types of cancer.[114]

SUMMARY OF FINDINGS AND RECOMMENDATIONS

On the basis of available data, we made several key findings. The manufacturing of MDI starts with fossil fuels and involves many different hazardous chemicals. MDI itself is also hazardous. In addition, the production of MDI generates hazardous chemical waste and releases into communities that are disproportionately people of color, low income, and/or linguistically isolated. These communities are home to many other manufacturing facilities that release hazardous chemicals, contributing to the cumulative chemical impacts experienced by the people who live there. Incidents at facilities throughout the MDI and SPF manufacturing supply chain have injured workers and resulted in shelter-in-place orders for nearby communities. Finally, there are many data gaps in understanding the impacts on workers and communities for the full life cycle of MDI in SPF insulation. Our findings are summarized in Table 8.

Below, we offer some recommendations based on the framework we developed using the principles of environmental justice and green chemistry.

Abide By Environmental Regulations

All of the companies in this report should comply with current environmental regulations. In addition, government agencies should increase facility inspections and penalties for violations. They should also strengthen the Risk Management Plan (RMP) Rule for high-risk chemical facilities to increase information and protections for people who live and work near high-risk chemical facilities.

Avoid Hazardous Chemicals and Prevent Pollution and Waste

The manufacturing of MDI uses a large number of hazardous chemicals and does not present much opportunity to improve the hazard profile of chemicals used in the process. The biggest opportunity is to move to different, nonhazardous chemistries or materials to achieve the same function.

Some spray foam manufacturers and other researchers have worked on alternative, isocyanate-free technologies.[115] It is unclear whether any isocyanate-free spray foams are currently available commercially and how these products would compare to spray polyurethane foam in terms of performance. Additional information on the composition and manufacture of these alternatives is needed to determine whether they would represent a reduction in chemical hazards throughout the manufacturing supply chain, during installation and use, and at end of life.

Reducing the generation of waste and the release of hazardous chemicals throughout the supply chain would represent an improvement over current processes. Manufacturers should decrease emissions below regulatory limits, which are derived by considering only individual facility impacts and a limited number of hazardous chemicals. They should implement additional pollution prevention and hazard reduction activities with the goal of eliminating all hazardous releases and waste.

Governments should adopt policies that center on avoiding hazardous chemicals and supporting green chemistry innovations. In addition, jurisdictions should mandate emissions reductions.

Implement Circularity and Reduce End-of-Life Impacts

There are no clear options for improvement at the end of life for spray foam insulation. The biggest opportunity is to move to different chemistries or materials that can be reused and recycled into similar or higher-value materials.

Jurisdictions should implement policies that support the development of products that can be safely reused and recycled as part of a circular economy.

Prevent Disproportionate and Cumulative Impacts

Abiding by environmental regulations, avoiding hazardous chemicals, preventing pollution and waste, and implementing end-of-life programs all contribute to the reduction of disproportionate and cumulative impacts on marginalized and overburdened communities.

Table 8. Summary of findings on MDI in SPF insulation and recommendations			
		Recommendations	
Case Study Criteria for Chemical and Environmental Justice Impacts	**Findings on MDI**	**For Manufacturers Throughout the Supply Chain**	**For Governments and Other Policymakers**
Avoid hazardous chemicals	More than 90% of chemicals used as inputs for MDI production are hazardous to human health. Half are highly reactive or flammable. More than 90% of chemical inputs for MDI production are volatile. We identified one hazardous by-product, hydrochloric acid. MDI itself is also hazardous.	Because the input and output chemicals are largely hazardous, there is little opportunity for improvements in the existing process. The biggest opportunity is to move to different, nonhazardous chemistries or materials to achieve the same function.	Adopt policies centered on hazard avoidance.
Prevent accidents	Incidents at facilities throughout the MDI manufacturing supply chain have injured workers and resulted in shelter-in-place orders for nearby communities.		
Prevent pollution and waste	Facilities manufacturing MDI in the United States report that they: ■ Generate 47.7 million pounds of hazardous MDI-related chemical waste on average each year (combined) ■ Release an average of 560,000 pounds of hazardous MDI-related chemicals into the air and water each year (combined)	Optimize process efficiency to reduce waste generation and implement pollution control measures to reduce air and water releases with the goal to eliminate all hazardous releases and waste.	Mandate emissions reductions.
Implement circularity and reduce end-of-life impacts	It is possible to use renewable materials for some inputs to MDI production, but the vast majority manufactured today are derived solely from petroleum. In the context of use in insulation, MDI is not reusable or recyclable at end of product life into similar or higher-value materials. SPF is primarily disposed of in landfills.	Because the physical properties of cured SPF make it essentially non-reusable or recyclable, the biggest opportunity is to move to different chemistries or materials to achieve the same function.	Implement policies that support the development of products that can safely be reused and recycled as part of a circular economy. Support transparency about material content as a part of circularity efforts.
Abide by environmental regulations	75% of MDI facilities have had significant violations of EPA regulations within the last 12 quarters (3 years). 50% of facilities have had significant violations for all of the last 12 quarters.	Abide by environmental regulations.	Increase facility inspections and enforcement actions. Strengthen the Risk Management Plan (RMP) Rule to increase information and protections for people who live and work near high-risk chemical facilities.

Table 8. (continued) Summary of findings on MDI in SPF insulation and recommendations			
Prevent disproportionate and cumulative impacts	Compared with the United States overall, the communities surrounding MDI manufacturing facilities have a higher percentage Latino, Black, and/or American Indian/Alaska Native population. Two of the communities have a higher percentage of linguistically isolated households, and one also has a higher percentage of low-income households. These fenceline communities also have a greater percentage of children than the nation overall. Cities where MDI manufacturing is located are home to 18–29 facilities that release and/or manage hazardous chemicals. Reported cumulative on-site releases of hazardous chemicals from all these facilities ranged from about 4 million to 15 million pounds in each city in 2019.	Pursue all of the above help reduce disproportionate and cumulative impacts. Do not expand or build new facilities that will increase hazardous chemical releases in marginalized and overburdened communities. Use standard frameworks to assess and guide improvements related to broader social equity impacts. Provide disclosure of material content and emissions to support workers' and communities' right to know about hazardous chemicals that may impact them.	Pursue all of the above to help reduce disproportionate and cumulative impacts. Adopt policies that account for cumulative impacts in permitting decisions. Support transparency about material content, emissions, and location of manufacture.

In addition, companies should not expand or build new facilities that will increase hazardous chemical releases in marginalized and overburdened communities.

Outside of reducing chemical impacts, manufacturers can strive to be good neighbors in the communities where they are located and along the supply chain, through activities such as hiring local workers and contributing to local economic development. Companies can use the Social Life Cycle Assessment methodology developed by the United Nations Environment Programme, or similar analysis, to assess the social equity impacts of their products and organizations and guide improvements.[116]

Beyond manufacturer actions, jurisdictions should adopt policies that account for cumulative impacts in their permitting decisions.[117]

Disclose Material Content and Emissions

We need a more complete picture of the chemical and material flows for MDI manufacturing, a better understanding of worker exposures at each stage of manufacturing, and a clearer view of the impacts on residents in the surrounding communities, including the combined impacts on communities from chemical and nonchemical stressors.

Manufacturers at each step of the supply chain of insulation products should provide transparency on material content and emissions, tied to location, to support the right of downstream manufacturers, workers, and communities to know about hazardous chemicals that may impact them. This would also support future efforts to reuse and recycle products.

CONCLUSION

The chemical impacts of a product extend in both directions from product manufacturing—including fossil fuel extraction and chemical production to the disposal of waste chemicals and products. Harm to people and the environment can occur at each of these steps, contributing to the embodied chemical impacts of a product. Through this case study, we have developed and applied a new framework for measuring some important chemical and environmental justice impacts. This framework can be used both to identify opportunities to reduce these impacts for a particular chemical or material and to compare the impacts of different chemicals or materials. It can be applied to any material, including those outside the built environment.

This case study is not inclusive of all potentially hazardous chemicals that may be used in the production of MDI or all the potential impacts on workers and communities. A more complete understanding of the embodied chemical impacts of SPF insulation requires additional data on upstream impacts such as fossil fuel extraction, on chemical impacts of the other 50 percent of chemicals that make up SPF insulation materials, and on production volumes tied to quantity of releases and waste. This case study does, however, provide a view into some of the hazards and impacts as well as opportunities to reduce these impacts.

To support a more equitable and sustainable built environment, manufacturers throughout the life cycle of products should follow green chemistry and environmental justice principles. They should avoid hazardous chemicals; prevent accidents, pollution, and waste; implement circularity and reduce end-of-life impacts; and prevent disproportionate or cumulative impacts.

Governments (local, state, and federal) should increase enforcement, inspections, and penalties for violations of existing laws. At the same time, governments should advance policies that require facilities throughout the supply chain to reduce emissions, strengthen protections for people who live and work near high-risk chemical facilities, account for cumulative impacts in permitting decisions, and support green chemistry innovations.

This case study can also help building industry professionals start to understand the embodied chemical impacts of materials. This awareness can then lead to demands for additional transparency on the part of manufacturers. Transparency about what is in a product, how the product is made, and hazardous emissions—beyond the reporting required by law—is critical. In the meantime, building industry professionals can work toward avoiding products that contain hazardous chemicals. As a starting point, this helps protect not only building occupants and installers, but others impacted by those hazardous chemicals at other points in the supply chain. Healthy Building Network's product guidance can help professionals choose safer product types on the basis of what we know today as we work to expand our research into life cycle chemical impacts and to provide guidance on a broader range of materials.[i]

A similar case study considering glass fibers in fiberglass insulation is available for comparison of these two inputs and types of insulation. A fact sheet summarizing the framework and offering recommendations is also available.[j]

[i] Healthy Building Network's product guidance is available here: https://healthybuilding.net/products
[j] The case studies and fact sheet are available here: https://healthybuilding.net/reports.

APPENDIX 1: PRINCIPLES OF GREEN CHEMISTRY AND PRINCIPLES OF ENVIRONMENTAL JUSTICE

12 Principles of Green Chemistry[118]

1. **Prevention.** It is better to prevent waste than to treat or clean up waste after it has been created.
2. **Atom Economy.** Synthetic methods should be designed to maximize incorporation of all materials used in the process into the final product.
3. **Less Hazardous Chemical Syntheses.** Whenever practicable, synthetic methods should be designed to use and generate substances that possess little or no toxicity to human health and the environment.
4. **Designing Safer Chemicals.** Chemical products should be designed to preserve efficacy of function while reducing toxicity.
5. **Safer Solvents and Auxiliaries.** The use of auxiliary substances (e.g., solvents, separation agents, etc.) should be made unnecessary whenever possible and innocuous when used.
6. **Design for Energy Efficiency.** Energy requirements should be recognized for their environmental and economic impacts and should be minimized. Synthetic methods should be conducted at ambient temperature and pressure.
7. **Use of Renewable Feedstocks.** A raw material or feedstock should be renewable rather than depleting whenever technically and economically practicable.
8. **Reduce Derivatives.** Unnecessary derivatization (use of blocking groups, protection/deprotection, temporary modification of physical/chemical processes) should be minimized or avoided if possible, because such steps require additional reagents and can generate waste.
9. **Catalysis.** Catalytic reagents (as selective as possible) are superior to stoichiometric reagents.
10. **Design for Degradation.** Chemical products should be designed so that at the end of their function they break down into innocuous degradation products and do not persist in the environment.
11. **Real-Time Analysis for Pollution Prevention.** Analytical methodologies need to be further developed to allow for real-time, in-process monitoring and control prior to the formation of hazardous substances.
12. **Inherently Safer Chemistry for Accident Prevention.** Substances and the form of a substance used in a chemical process should be chosen to minimize the potential for chemical accidents, including releases, explosions and fires.

17 Principles of Environmental Justice[119]

1. Environmental Justice affirms the sacredness of Mother Earth, ecological unity and the interdependence of all species, and the right to be free from ecological destruction.
2. Environmental Justice demands that public policy be based on mutual respect and justice for all peoples, free from any form of discrimination or bias.
3. Environmental Justice mandates the right to ethical, balanced and responsible uses of land and renewable resources in the interest of a sustainable planet for humans and other living things.
4. Environmental Justice calls for universal protection from nuclear testing, extraction, production and disposal of toxic/hazardous wastes and poisons that threaten the fundamental right to clean air, land, water, and food.
5. Environmental Justice affirms the fundamental right to political, economic, cultural, and environmental self-determination of all peoples.
6. Environmental Justice demands the cessation of the production of all toxins, hazardous wastes, and radioactive materials, and that all past and current producers be held strictly accountable to the people for detoxification and the containment at the point of production.
7. Environmental Justice demands the right to participate as equal partners at every level of decision-making, including needs assessment, planning, implementation, enforcement and evaluation.
8. Environmental Justice affirms the right of all workers to a safe and healthy work environment without being forced to choose between an unsafe livelihood and unemployment. It also affirms the right of those who work at home to be free from environmental hazards.
9. Environmental Justice protects the right of victims of environmental injustice to receive full compensation and reparations for damages as well as quality health care.
10. Environmental Justice considers governmental acts of environmental injustice a violation of international law, the Universal Declaration On Human Rights, and the United Nations Convention on Genocide.
11. Environmental Justice must recognize a special legal and natural relationship of Native Peoples to the U.S. government through treaties, agreements, compacts, and covenants affirming sovereignty and self-determination.
12. Environmental Justice affirms the need for urban and rural ecological policies to clean up and rebuild our cities and rural areas in balance with nature, honoring the cultural integrity of all our communities, and provided fair access for all to the full range of resources.
13. Environmental Justice calls for the strict enforcement of principles of informed consent, and a halt to the testing of experimental reproductive and medical procedures and vaccinations on people of color.
14. Environmental Justice opposes the destructive operations of multi-national corporations.
15. Environmental Justice opposes military occupation, repression and exploitation of lands, peoples and cultures, and other life forms.
16. Environmental Justice calls for the education of present and future generations which emphasizes social and environmental issues, based on our experience and an appreciation of our diverse cultural perspectives.
17. Environmental Justice requires that we, as individuals, make personal and consumer choices to consume as little of Mother Earth's resources and to produce as little waste as possible; and make the conscious decision to challenge and reprioritize our lifestyles to ensure the health of the natural world for present and future generations.

APPENDIX 2: STATE-LEVEL DEMOGRAPHIC INFORMATION

The demographic analysis in this case study considers populations in four fenceline zones in two states, compared with the U.S. population overall. Within the nation, there can be significant regional variations in demographics among different states and locales. Comparing fenceline zone demographics with more localized demographic data can highlight additional disparities beyond those observed at the national level. It is important to note that while fenceline demographics can sometimes mirror state-level data more closely than it mirrors national data, this does not negate the fact that communities in the fenceline zones are disproportionately people of color, low income, and linguistically isolated.

The state-level demographic data show that the four facilities are located in states that have larger percentages of people of color, especially Black and Latino populations, than in the United States overall. The percentages of people of color in the fenceline zone for the Dow facility are not only higher than in the nation overall, but also significantly higher than for the state where the facility is located.

Table A1. Summary of demographic information for residents within three miles of each MDI manufacturing facility, compared with data for states in which the facilities are located.

	Rubicon (LA)	BASF (LA)	Louisiana	Dow (TX)	Covestro (TX)	Texas	U.S. Overall
	Percentage of Population						
Hispanic or Latino	5%	5%	5%	60%	37%	39%	18%
White Non-Hispanic	61%	62%	59%	23%	49%	42%	61%
Black or African American	32%	31%	32%	12%	11%	12%	12%
American Indian or Alaska Native	0%	0%	0.5%	3%	0%	0.2%	0.7%
Asian	2%	2%	2%	1%	1%	5%	5%
Native Hawaiian or Other Pacific Islander	0%	0%	0%	0%	0%	0.1%	0.2%
Other Race	0%	0%	0.2%	0%	0%	0.2%	0.2%
Two or More Races	0.3%	0.3%	2%	2%	2%	2%	2%
People of Color	39%	38%	41%	77%	51%	58%	39%

Orange highlights indicate where the percentage of historically marginalized populations is greater in the fenceline zone than in the state where the facility is located. The ACS reports both on race (white, Black, Asian, American Indian or Alaska Native, Native Hawaiian or other Pacific Islander, other race, or two or more races) and on ethnicity (Hispanic or Latino). Hispanic or Latino individuals will also fall into one or more of the race categories. To avoid double-counting individuals, this table includes individuals reporting Hispanic or Latino in the row for Hispanic or Latino. Individuals reporting non-Hispanic or Latino are included in the subsequent rows. See text box, "More on the EPA's EJScreen," for definitions of people of color.

Sources: EPA's EJScreen and U.S. Census Bureau American Community Survey five-year estimates for 2014–2018.[120]

APPENDIX 3: SUPPLEMENTAL TABLES

Table A2. Average annual waste of MDI-related chemicals and percentage released or disposed of on site, 2015–2019.

	Covestro Baytown, TX	Dow Freeport, TX	Rubicon Geismar, LA	BASF Geismar, LA
Average annual waste reported, 2015–2019 (lbs.)	3,038,852	21,447,252	8,006,016	15,198,783
Percentage of waste released or disposed of on site, 2015–2019	7%	99%	98%	97%

Amounts are not directly comparable among facilities on a per MDI production basis; see text for more explanation.

Source: EPA Toxics Release Inventory.

Table A3. Total air and water releases in 2019.

	Covestro Baytown, TX	Dow Freeport, TX	Rubicon Geismar, LA	BASF Geismar, LA
Total TRI-Reported Air and Water Releases from the Facility in 2019 (lbs.)	483,785	873,950	328,235	2,085,558

Source: EPA Toxics Release Inventory.

Table A4. Number of TRI facilities and total on-site releases in 2019 for the cities where MDI is manufactured

City	# of TRI Facilities	Total On-Site Releases to Air, Water, and Land in 2019 Reported to TRI (lbs.)
Geismar, LA	18	15,349,556
Freeport, TX	21	3,928,043
Baytown, TX	29	5,541,899

Source: EPA Toxics Release Inventory.

Endnotes

1 Carbon Leadership Forum, "Embodied Carbon 101," December 17, 2020, https://carbonleadershipforum.org/download/13878/.

2 Arne Remmen, Allan A. Jensen, and Jeppe Frydendal, "Life Cycle Management: A Business Guide to Sustainability," United Nations Environment Programme, 2007, https://wedocs.unep.org/bitstream/handle/20.500.11822/7894/DTI0889PA.pdf?sequence=3&amp%3BisAllowed=.

3 U.S. Environmental Protection Agency (hereinafter EPA), Office of Chemical Safety and Pollution Prevention, "Basics of Green Chemistry," Overviews and Factsheets, February 12, 2013, https://www.epa.gov/greenchemistry/basics-green-chemistry. EPA, "Environmental Justice," https://www.epa.gov/environmentaljustice (accessed November 8, 2021).

4 Energy Efficiency for All, "Healthy Affordable Building Materials," https://www.energyefficiencyforall.org/initiatives/healthybuildingmaterials/ (accessed August 12, 2021).

5 Energy Efficiency for All, "Making Affordable Multifamily Housing More Energy Efficient: A Guide to Healthier Upgrade Materials," September 2018, https://s3.amazonaws.com/hbnweb.dev/uploads/files/Qj5q/NRDC-3084%20Guide%20to%20Healthier%20Retrofit_Final.pdf.

6 Energy Efficiency for All, Making Affordable Multifamily Housing More Energy Efficient: A Guide to Healthier Upgrade Materials, September 2018, https://s3.amazonaws.com/hbnweb.dev/uploads/files/Qj5q/NRDC-3084%20Guide%20to%20Healthier%20Retrofit_Final.pdf.

7 Healthy Building Network, "Common Product: Closed Cell Spray Foam Insulation," Pharos, 2021, https://pharosproject.net/common-products/2079008#contents-panel. Jack Wisniewski, "Is Foam Roofing Worth the Cost? Pros, Cons, and Verdict," Roofing Calculator, November 18, 2020, https://roofingcalculator.com/news/pros-and-cons-of-foam-roofing.

8 Lucintel, Spray Foam Insulation Market Report: Trends, Forecast and Competitive Analysis, ReportLinker, August 2020, https://www.reportlinker.com/p05576280/Spray-Foam-Insulation-Market-Report-Trends-Forecast-and-Competitive-Analysis.html. Dennis Fengmao Guo et al., "Summary of Technical Information and Scientific Conclusions for Designating Spray Polyurethane Foam Systems With Unreacted Methylene Diphenyl Diisocyanates as a Priority Product," Safer Products and Workplaces Program, California Environmental Protection Agency, Department of Toxic Substances Control, February 2017, http://www.dtsc.ca.gov/SCP/upload/SPF-Systems-Summary-of-Technical-Information.pdf.

9 Lucintel, Spray Foam Insulation Market Report.

10 Guo et al., "Summary of Technical Information."

11 "Foam Insulation Continues to Grow SF Market Share," SBC Magazine, July 31, 2019, https://www.sbcmag.info/news/2019/jul/foam-insulation-continues-grow-sf-market-share.

12 Guo et al., "Summary of Technical Information."

13 Beth Hawkins, Michaela Marincic, and Erin Rose, "Drivers, Adoptability, and Performance of Healthier Energy-Efficiency Retrofit Materials in Affordable Multifamily Housing," Energy Efficiency for All, August 2019, https://assets.ctfassets.net/ntcn17ss1ow9/2xwM8epxASsSemkkI5JW2F/8bcdcaacb947558ef967adc23bfde7cd/NRDC-3098_EE_Drivers_Adoptability_and_Performace_Report_FINAL.pdf.

14 ECTC Chemical Technologies, "Isocyanates Production: Global and Russian Isocyanate Market Overview," April 29, 2019, https://ect-center.com/blog-en/global-isocyanate-market. ReportLinker, "Global Diphenylmethane Diisocyanate (MDI) Industry," GlobeNewswire News Room, November 20, 2020, http://www.globenewswire.com/news-release/2020/11/20/2130885/0/en/Global-Diphenylmethane-Diisocyanate-MDI-Industry.html. EPA, "Methylene Diphenyl Diisocyanate (MDI) and Related Compounds Action Plan [RIN 2070-ZA15]," April 2011, https://www.epa.gov/sites/production/files/2015-09/documents/mdi.pdf.

15 EPA, "Methylene Diphenyl Diisocyanate."

16 ECTC Chemical Technologies, "Isocyanates Production." Market Watch, "Methylene Diphenyl Di-Isocyanate (MDI) Market 2020: Regional Analysis With Top Countries Data, Trends, Definition, Share, Market Size and Forecast Report by 2026," December 2, 2020, https://www.marketwatch.com/press-release/methylene-diphenyl-di-isocyanate-mdi-market-2020-regional-analysis-with-top-countries-data-trends-definition-share-market-size-and-forecast-report-by-2026-2020-12-02. ReportLinker, "Global Diphenylmethane Diisocyanate (MDI) Industry."

17 ReportLinker, "Global Diphenylmethane Diisocyanate (MDI) Industry."

18 European Chemicals Agency (hereinafter ECHA), "ECHA Substance Infocard -4,4'-Methylenediphenyl Diisocyanate," https://echa.europa.eu/substance-information/-/substanceinfo/100.002.697 (accessed January 21, 2021). Korean National Institute of Environmental Research, "National Chemicals Information System: Diphenylmethane 4,4'-Diisocyanate," https://ncis.nier.go.kr/en/mttrDetail.do (accessed January 21, 2021). New Zealand Environmental Protection Authority, "Chemical Classification and Information Database: Methylene, 4,4'-Diphenyl Diisocyanate-," https://www.epa.govt.nz/database-search/chemical-classification-and-information-database-ccid/view/3402 (accessed January 21, 2021). NITE-CHIRP, "NITE - GHS Information - Methylenebis(4,1-Phenylene) Diisocyanate," https://www.nite.go.jp/chem/english/ghs/15-mhlw-0104e.html (accessed January 21, 2021). Safe Work Australia, "Hazardous Chemical Information System Hazardous Chemical Details: Benzene, 1,1'-Methylenebis[4-Isocyanato-," http://hcis.safeworkaustralia.gov.au/HazardousChemical/Details?chemicalID=363 (accessed January 21, 2021).

19 U.S. Occupational Safety and Health Administration (hereinafter OSHA), "OSHA Fact Sheet: Do You Have Work-Related Asthma? A Guide for You and Your Doctor," March 2014, https://www.osha.gov/Publications/OSHA3707.pdf. Kenneth D. Rosenman, Mary Jo Reilly, and Barton G. Pickelman, "2019 Annual Report Tracking Work-Related Asthma in Michigan," Michigan State University Department of Medicine and Michigan Department of Labor and Economic Opportunity, July 20, 2020, https://oem.msu.edu/images/annual_reports/2019-WRA-Annual-Report-FINAL.pdf. Daniel Lefkowitz et al., "Isocyanates and Work-Related Asthma: Findings From California, Massachusetts, Michigan, and New Jersey, 1993–2008," American Journal of Industrial Medicine 58, no. 11 (November 2015): 1138–49, https://doi.org/10.1002/ajim.22527.

20 Rosenman, Reilly, and Pickelman, "2019 Annual Report." National Institute for Occupational Safety and Health (hereinafter NIOSH), "Work-Related Asthma: Exposures Most Frequently Reported by Work-Related Asthma Cases in California, Massachusetts, Michigan, and New York, 2009–2014," November 2020, https://wwwn.cdc.gov/eWorld/Grouping/Asthma/97.

21 Guo et al., "Summary of Technical Information."

22 EPA, "Methylene Diphenyl Diisocyanate."

23 BASF, "MDI Handbook: North America," 2019, https://polyurethanes.basf.us/files/pdf/2019-MDI-Handbook_EL.pdf. Rebe Feraldi et al., "Cradle-to-Gate Life Cycle Inventory of Nine Plastic Resins and Four Polyurethane Precursors," August 2011, https://www.researchgate.net/publication/297268002_Cradle-to-Gate_Life_Cycle_Inventory_of_Nine_Plastic_Resins_and_Four_Polyurethane_Precursors. I. Boustead, "Eco-Profiles of the European Plastics Industry: Diphenylmethane Diisocyanate (MDI)," PlasticsEurope, March 2005, https://web.archive.org/web/20180728162341/http://polyurethanes.org:80/uploads/documents/eco_midi.pdf.

24 EPA Office of Air Quality, "Locating and Estimating Air Emissions From Sources of Phosgene," September 1985, https://www3.epa.gov/ttnchie1/le/phosgene.pdf. Robert Henry Carr, Johannes Lodewijk Koole, and Udo Brian Dave Mike Rodger Bruinsma, "Process for Manufacturing Isocyanates," United States US8802890B2, patent application filed November 5, 2009, and issued August 12, 2014, https://patents.google.com/patent/US8802890B2/en.

25 Huntsman Corporation, "Transforming Plastic Waste Into Energy-Saving Insulation," https://www.huntsman.com/sustainability/our-impact/article/6867/transforming-plastic-waste-into-energy-saving-insulation (accessed March 22, 2021). Covestro AG, "Bio-Based Aniline: A Scientific Breakthrough for Greater Sustainability," https://www.covestro.com/en/sustainability/lighthouse-projects/bio-anilin (accessed April 16, 2021). "Polylabs to Present Innovative, Biobased Lightweight Spray Foam at Upcoming PSE," Bioplastics Magazine, May 16, 2017, https://www.bioplasticsmagazine.com/en/news/meldungen/15052017-Polylabs-to-present-new-biobased-spray-formulation-at-PSE.php.

26 Raymond Neff and Agnieszka Gajewski, "Renewable Building Blocks for Polyurethanes," Physical Sciences Reviews 3, no. 8 (August 1, 2018), https://doi.org/10.1515/psr-2017-0193.

27 Boustead, "Eco-Profiles." Feraldi et al., "Cradle-to-Gate Life Cycle Inventory." BASF, "MDI Handbook: North America." EPA Office of Air Quality, "Locating and Estimating Air Emissions." Carr, Koole, and Bruinsma, "Process for Manufacturing Isocyanates."

28 Association of Occupational and Environmental Clinics, "AOEC Exposure Code List," http://www.aoec.org/tools.htm (accessed May 17, 2021).

29 EPA, "Integrated Risk Information System (IRIS) Database," https://cfpub.epa.gov/ncea/iris/search/index.cfm?keyword= (accessed May 17, 2021). International Agency for Research on Cancer (hereinafter IARC), "IARC Monographs on the Identification of Carcinogenic Hazards to Humans," https://monographs.iarc.who.int/agents-classified-by-the-iarc/ (accessed May 17, 2021).

30 ECHA, "Classification and Labelling Inventory," https://echa.europa.eu/information-on-chemicals/cl-inventory-database (accessed May 17, 2021). IARC, "IARC Monographs." EPA, "Integrated Risk Information System (IRIS) Database."

31 EPA, "Volatile Organic Compounds' Impact on Indoor Air Quality," https://www.epa.gov/indoor-air-quality-iaq/volatile-organic-compounds-impact-indoor-air-quality (accessed December 14, 2021).

32 EPA, "Technical Overview of Volatile Organic Compounds," August 18, 2014, https://www.epa.gov/indoor-air-quality-iaq/technical-overview-volatile-organic-compounds.

33 Healthy Building Network, "Pharos," Pharos, accessed March 19, 2021, https://pharosproject.net. EPA, "TRI-Listed Chemicals," https://www.epa.gov/toxics-release-inventory-tri-program/tri-listed-chemicals (accessed March 12, 2021).

34 Clean Production Action, "GreenScreen for Safer Chemicals," https://www.greenscreenchemicals.org (accessed December 17, 2021).

35 ECHA, "PBT/VPvB Assessments Under the Previous EU Chemicals Legislation," 2007, https://echa.europa.eu/information-on-chemicals/pbt-vpvb-assessments-under-the-previous-eu-chemicals-legislation. EPA, "Priority Chemicals (NWMP)," February 22, 2016, https://archive.epa.gov/epawaste/hazard/wastemin/web/html/priority.html.

36 EPA, "Technical Overview of Volatile Organic Compounds."

37 U.S. National Library of Medicine, "ChemIDplus," https://chem.nlm.nih.gov/chemidplus/ (accessed August 23, 2021). ECHA, "Registered Substances," https://echa.europa.eu/information-on-chemicals/registered-substances?p_p_id=dissregisteredsubstances_WAR_dissregsubsportlet&p_p_lifecycle=1&p_p_state=normal&p_p_mode=view&_dissregisteredsubstances_WAR_dissregsubsportlet_javax.portlet.action=dissRegisteredSubstancesAction (accessed August 23, 2021).

38 EPA, "Interpreting the CDR Data," March 21, 2013, https://www.epa.gov/chemical-data-reporting/interpreting-cdr-data.

39 Spray Polyurethane Foam Alliance (hereinafter SPFA), "Environmental Product Declaration: Spray Polyurethane Foam Insulation (HFC)," October 29, 2018, https://www.astm.org/CERTIFICATION/DOCS/414.EPD_for_SPFA-EPD-20181029-HFC.pdf. Daniela Rechenberger, "BASF Reaches Milestone of MDI Capacity Expansion Project at Geismar Site," BASF, December 16, 2020, https://www.basf.com/global/en/media/news-releases/2020/12/p-20-395.html. Zachary Moore, "Dow Declares Force Majeure on U.S. MDI," Borderless, October 2, 2020, https://www.borderless.net/news/chemical-value-chain/dow-declares-force-majeure-on-us-mdi/. Kristen Mosbrucker, "Huntsman Considers $270M Plant Expansion in Geismar," The Advocate, September 6, 2019, https://www.theadvocate.com/baton_rouge/news/business/article_0e59ff3c-d0b4-11e9-9e68-bf6cf475846f.html. Covestro AG, "Welcome to Covestro," March 7, 2016, https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwipu5eSqKP2AhXillkEHbJJBhIQFnoECAkQAQ&url=https%3A%2F%2Fwww.covestro.com%2F-%2Fmedia%2Fcovestro%2Fcorporate%2Finvestors%2Ffinancial-documents-and-presentations%2Fpresentations-and-documents%2F2016%2F160307_covestro_deutsche_bank_us_chemicals_fieldtrip_2016.pdf&usg=AOvVaw26QKJazzMHtLc-_s6fpG6w.

40 Covestro AG, "Welcome to Covestro." Moore, "Dow Declares Force Majeure." Rechenberger, "BASF Reaches Milestone." Mosbrucker, "Huntsman Considers $270M Plant Expansion."

41 Environmental Justice Health Alliance and Coming Clean, "Life at the Fenceline: Understanding Cumulative Health Hazards in Environmental Justice Communities," September 2018, https://ej4all.org/life-at-the-fenceline. CleanAirNow, "CleanAirNow Environmental Justice Recommendations: Comments on the Armourdale General Plan," May 2021, https://ucs-documents.s3.amazonaws.com/misc/armourdale-general-plan.pdf. The Climate Reality Project, "Let's Talk about Sacrifice Zones," May 13, 2021, https://www.climaterealityproject.org/blog/lets-talk-about-sacrifice-zones.

42 EPA, "EJScreen," 2020, www.epa.gov/ejscreen.

43 Jae M. Sevelius et al., "Research with Marginalized Communities: Challenges to Continuity During the COVID-19 Pandemic," AIDS and Behavior 24, no. 7 (2020): 2009-2012. https://doi.org/10.1007/s10461-020-02920-3.

44 Foster Osei Baah et al., "Marginalization: Conceptualizing patient vulnerabilities in the framework of social determinants of health-An integrative review," Nursing Inquiry 26, no. 1 (2019): e12268, https://doi.org/10.1111/nin.12268.

45 See Toxic Risk, "Rubicon Inc.: Executive Summary," 1999, https://toxicrisk.com/reports/13664/summary.htm.

46 EPA, "Overview of Demographic Indicators in EJScreen," March 5, 2021, https://www.epa.gov/ejscreen/overview-demographic-indicators-ejscreen.

47 EPA, "What Is EJScreen?," Overviews and Factsheets, October 28, 2019, https://www.epa.gov/ejscreen/what-ejscreen.

48 EPA, "Technical Information About EJScreen," last updated August 23, 2021, https://www.epa.gov/ejscreen/technical-information-about-ejscreen.

49 Facility-level fenceline data are from EPA, "EJScreen." Nationwide data are from U.S. Census Bureau, "ACS Demographic and Housing Estimates, 2018: ACS 5-Year Estimates Data Profiles," Census Data Exploration Portal, https://data.census.gov/cedsci/table?q=United%20States&tid=ACSDP5Y2018.DP05 (accessed May 12, 2021).

50 Commission for Environmental Cooperation, Toxic Chemicals and Children's Health in North America: A Call for Efforts to Determine the Sources, Levels of Exposure, and Risks That Industrial Chemicals Pose to Children's Health, 2006, http://www3.cec.org/islandora/en/item/2280-toxic-chemicals-and-childrens-health-in-north-america-en.pdf. Mark D. Miller et al., "Differences Between Children and Adults: Implications for Risk Assessment at California EPA," International Journal of Toxicology 21, no. 5 (October 2002): 403–18, https://doi.org/10.1080/10915810290096630.

51 EPA, "What Is the Toxics Release Inventory?" January 14, 2021, https://www.epa.gov/toxics-release-inventory-tri-program/what-toxics-release-inventory.

52 EPA, "Substance Details: Diisocyanates—TRI," https://sor.epa.gov/sor_internet/registry/substreg/substance/details.do?displayPopup=&id=35885 (accessed March 12, 2021).

53 EPA, "Pollution Prevention (P2) and TRI," March 3, 2013, https://www.epa.gov/toxics-release-inventory-tri-program/pollution-prevention-p2-and-tri.

54 EPA, "Common TRI Terms," https://www.epa.gov/toxics-release-inventory-tri-program/common-tri-terms (accessed August 23, 2021).

55 Ibid.

56 Ibid.

57 Peter W. Tait et al., "The Health Impacts of Waste Incineration: A Systematic Review," Australian and New Zealand Journal of Public Health 44, no. 1 (2020): 40–48, https://doi.org/10.1111/1753-6405.12939. Jose L. Domingo et al., "Adverse Health Effects for Populations Living Near Waste Incinerators With Special Attention to Hazardous Waste Incinerators: A Review of the Scientific Literature," Environmental Research 187 (August 1, 2020): 109631, https://doi.org/10.1016/j.envres.2020.109631.

58 EPA, "Class I Industrial and Municipal Waste Disposal Wells," September 6, 2016, https://www.epa.gov/uic/class-i-industrial-and-municipal-waste-disposal-wells. EPA, "Class I Underground Injection Control Program: Study of the Risks Associated With Class I Underground Injection Wells," March 2001, https://www.epa.gov/sites/production/files/2015-07/documents/study_uic-class1_study_risks_class1.pdf.

59 Abrahm Lustgarten, "Injection Wells: The Poison Beneath Us," ProPublica, June 21, 2012, https://www.propublica.org/article/injection-wells-the-poison-beneath-us?token=k6QugzdODUjV_Y9Kbj1hdsw5gEohLUVV.

60 U.S. Geological Survey, "How Does the Injection of Fluid at Depth Cause Earthquakes?" https://www.usgs.gov/faqs/how-does-injection-fluid-depth-cause-earthquakes?qt-news_science_products=0#qt-news_science_products (accessed May 10, 2021).

61 EPA, "Pollution Prevention (P2) and TRI."

62 EPA, "Enforcement and Compliance History Online: Frequently Asked Questions," https://echo.epa.gov/resources/general-info/echo-faq (accessed September 21, 2021).

63 EPA, "Enforcement and Compliance History Online," https://echo.epa.gov/ (accessed May 11, 2021).

64 Ibid.

65 EPA, "Methylene Diphenyl Diisocyanate." Dhimiter Bello et al., "Skin Exposure to Isocyanates: Reasons for Concern," Environmental Health Perspectives 115, no. 3 (March 2007): 328–35, https://doi.org/10.1289/ehp.9557.

66 EPA, "Methylene Diphenyl Diisocyanate."

67 EPA, "Chemical Data Reporting: Completing Form U," February 26, 2016, https://www.epa.gov/chemical-data-reporting/completing-form-u.

68 NIOSH, "Hierarchy of Controls," January 13, 2015, https://www.cdc.gov/niosh/topics/hierarchy/.

69 OSHA, "Inspection Detail: Inspection 1222067.015, Covestro LLC," March 6, 2018, https://www.osha.gov/pls/imis/establishment.inspection_detail?id=1222067.015.

70 Mark Schleifstein, "Worker Exposure to Dangerous Chemicals at Rubicon Plant in Geismar Linked to Poor Maintenance Record," NOLA.com, January 3, 2021, https://www.nola.com/news/environment/article_3cffa794-5f1e-11ea-b203-4b0f231b21a8.html.

71 Sara Sneath, " 'Ticking Time Bombs': Residents Kept in the Dark About Risks to La.'s Chemical Plants During Storms," WWNO News, December 7, 2020, https://www.wwno.org/post/ticking-time-bombs-residents-kept-dark-about-risks-las-chemical-plants-during-storms.

72 John Schwartz and Hiroko Tabuchi, "When Hurricanes Lead to Industrial Fires, Minority Neighborhoods Can Take a Hit," New York Times, August 27, 2020, https://www.nytimes.com/2020/08/27/climate/hurricane-laura-fire-pollution.html. Sneath, " 'Ticking Time Bombs.' "

73 Catherine Fraser, "Refineries, Chemical Plants Release Over 4 Million Pounds of Pollution as a Result of Hurricane Laura," Environment Texas, August 26, 2020, https://environmenttexas.org/blogs/blog/txe/refineries-chemical-plants-release-over-4-millions-pounds-pollution-result-hurricane.

74 Texas Commission on Environmental Quality, "Air Emission Event Report Database Incident 350715," February 25, 2021, https://www2.tceq.texas.gov/oce/eer/index.cfm?fuseaction=main.getDetails&target=350715.

75 Michelle L. Bell and Keita Ebisu, "Environmental Inequality in Exposures to Airborne Particulate Matter Components in the United States," Environmental Health Perspectives 120, no. 12 (December 1, 2012): 1699–1704, https://doi.org/10.1289/ehp.1205201. Michael Gochfeld and Joanna Burger, "Disproportionate Exposures in Environmental Justice and Other Populations: The Importance of Outliers," American Journal of Public Health 101, no. Suppl 1 (December 2011): S53–63, https://doi.org/10.2105/AJPH.2011.300121. EPA, Environmental Equality: Reducing Risk for All Communities, volume 1, "Workgroup Report to Administrator," June 1992, https://www.epa.gov/sites/production/files/2015-02/documents/reducing_risk_com_vol1.pdf.

76 G. M. Solomon et al., "Cumulative Environmental Impacts: Science and Policy to Protect Communities," Annual Review of Public Health 37, no. 1 (March 2016), 83–96, https://doi.org/10.1146/annurev-publhealth-032315-021807. Yukyan Lam et al., "Toxic Air Pollution in the Houston Ship Channel: Disparities Show Urgent Need for Environmental Justice," Natural Resources Defense Council and Texas Environmental Justice Advocacy Services, September 2021, https://www.nrdc.org/resources/toxic-air-pollution-houston-ship-channel-disparities-show-urgent-need-environmental.

77 New Jersey Department of Environmental Protection, "What Are Overburdened Communities (OBC)?" https://www.nj.gov/dep/ej/communities.html (accessed June 23, 2022).

78 Ken Sexton, "Cumulative Risk Assessment: An Overview of Methodological Approaches for Evaluating Combined Health Effects From Exposure to Multiple Environmental Stressors," International Journal of Environmental Research and Public Health 9, no. 2 (February 2012): 370–90, https://doi.org/10.3390/ijerph9020370.

79 Tristan Baurick, Lylla Younes, and Joan Meiners, "Welcome to 'Cancer Alley,' Where Toxic Air Is About to Get Worse," ProPublica, October 30, 2019, https://www.propublica.org/article/welcome-to-cancer-alley-where-toxic-air-is-about-to-get-worse?token=6gUgP8l5cJIpT-zNaKZUM1en4qd5mMoT. James Pasley, "Inside Louisiana's Horrifying 'Cancer Alley,' an 85-Mile Stretch of Pollution and Environmental Racism That's Now Dealing With Some of the Highest Coronavirus Death Rates in the Country," Business Insider, April 9, 2020, https://www.businessinsider.com/louisiana-cancer-alley-photos-oil-refineries-chemicals-pollution-2019-11. Forensic Architecture, "Environmental Racism in Death Alley, Louisiana: Phase I Investigative Report," July 4, 2021, https://forensic-architecture.org/investigation/environmental-racism-in-death-alley-louisiana.

80 Union of Concerned Scientists, "Environmental Impacts of Natural Gas," June 19, 2014, https://www.ucsusa.org/resources/environmental-impacts-natural-gas. Tim Donaghy and Charlie Jiang, "Fossil Fuel Racism: How Phasing Out Oil, Gas, and Coal Can Protect Communities," Greenpeace Reports, April 13, 2021, https://www.greenpeace.org/usa/reports/fossil-fuel-racism/.

81 Dennie Mah, John W. Weidner, and Sathya Motupally, "Report on the Electrolytic Industries for the Year 1998," Journal of the Electrochemical Society 146, no. 10 (October 1999): 3924–47, https://iopscience.iop.org/article/10.1149/1.1392574. Jim Vallette, Chlorine and Building Materials: A Global Inventory of Production Technologies, Markets, and Pollution. Phase 1: Africa, the Americas, and Europe, Healthy Building Network, July 2018, https://s3.amazonaws.com/hbnweb.dev/uploads/files/wnxz/Chlorine%20%26%20Building%20Materials%20Phase%201%20-%20v2.pdf.

82 Mayra Quirindongo et al., "Lost and Found: Missing Mercury From Chemical Plants Pollutes Air and Water," NRDC, April 2006, https://www.nrdc.org/sites/default/files/chlor.pdf.

83 Vallette, Chlorine and Building Materials, Phase 1.

84 U.S. Geological Survey, "Mineral Commodity Summaries: Asbestos," January 2020, https://pubs.usgs.gov/periodicals/mcs2020/mcs2020-asbestos.pdf. Vallette, Chlorine and Building Materials, Phase 1. Jim Vallette, Chlorine & Building Materials Project: Phase 2 Asia Including Worldwide Findings, Healthy Building Network, March 2019, https://healthybuilding.net/reports/20-chlorine-building-materials-project-phase-2-asia-including-worldwide-findings.

85 EPA, "Basic Information on PFAS," https://www.epa.gov/pfas/basic-information-pfas (accessed August 24, 2021).

86 Mingbao Feng et al., "Characterization of the Thermolysis Products of Nafion Membrane: A Potential Source of Perfluorinated Compounds in the Environment," Scientific Reports 5, no. 1 (May 7, 2015): 9859, https://doi.org/10.1038/srep09859. Nadine Kotlarz et al., "Measurement of Novel, Drinking Water–Associated PFAS in Blood From Adults and Children in Wilmington, North Carolina," Environmental Health Perspectives 128, no. 7 (July 22, 2020), https://doi.org/10.1289/EHP6837.

87 Vallette, Chlorine and Building Materials, Phase 1.

88 Ibid.

89 Samantha Morgan, "Three Workers Hospitalized After Chlorine Release Chemical Plant," WLOX-TV, December 29, 2014, http://www.wlox.com/story/27723243/three-workers-hospitalized-after-chlorine-release-chemical-plant.

90 "Chlorine Leak at Area Plant Contained, Shelter in Place Order Lifted," WBRZ-TV, July 8, 2017, http://www.wbrz.com/news/chlorine-leak-at-area-plant-contained-shelter-in-place-order-lifted/. Wanderlog, "Saint Gabriel, Louisiana Weather in July," https://wanderlog.com/weather/71872/7/saint-gabriel-weather-in-july (accessed May 12, 2022).

91 Chemical Online, "Dow's Freeport PMDI Facility Now Fully Operational," May 30, 2006, https://www.chemicalonline.com/doc/dows-freeport-pmdi-facility-now-fully-operati-0001. Chemical Processing, "Dow Plans New MDI Facility in Freeport, Texas," June 15, 2021, https://www.chemicalprocessing.com/industrynews/2021/dow-plans-new-mdi-facility-in-freeport-texas/.

92 SPFA, "Environmental Product Declaration: Spray Polyurethane Foam Insulation (HFC)."

93 Mosbrucker, "Huntsman Considers $270M Plant Expansion."

94 Huntsman Corporation, "Huntsman Completes the Acquisition of Icynene-Lapolla, Expanding Its Downstream Footprint in Spray Polyurethane Foam Insulation," February 20, 2020, https://www.prnewswire.com/news-releases/huntsman-completes-the-acquisition-of-icynene-lapolla-expanding-its-downstream-footprint-in-spray-polyurethane-foam-insulation-301008756.html.

95 Huntsman Building Solutions, "Environmental Product Declaration: Heatlok HFO and Heatlok Soya HFO," January 1, 2021, https://spot.ul.com/main-app/products/detail/600f2356707850657811048d?page_type=Products%20Catalog. Service Partners, "Demilec—Spray Foam Insulation," https://www.service-partners.com/brand/demilec/ (accessed March 12, 2021). Huntsman Corporation, "Huntsman Completes."

96 EPA, "Toxic Chemical Release Inventory Reporting Forms and Instructions: Revised 2020 Version," March 2021, https://ofmpub.epa.gov/apex/guideme_ext/guideme/file/ry_2020_rfi.pdf. Demilec, "Safety Data Sheet: Heatlok Eco B-Side," September 19, 2019, https://www.demilec.com/es/sites/demilec.com.es/files/2019-10/Heatlok%20Eco%20B-Side%20SDS.pdf. Icynene-Lapolla, "Safety Data Sheet: ProSeal (MD-C-1200v3)," September 14, 2018, https://www.pharosproject.net/sources/viewFile/45986.

97 Service Partners, "BASF—Spray Foam Insulation," https://www.service-partners.com/brand/basf/ (accessed March 12, 2021).

98 L. Fazzo et al., "Hazardous Waste and Health Impact: A Systematic Review of the Scientific Literature," Environmental Health 16, no. 1 (October 11, 2017): 107, https://doi.org/10.1186/s12940-017-0311-8. Tait et al., "The Health Impacts of Waste Incineration." Domingo et al., "Adverse Health Effects for Populations Living Near Waste Incinerators."

99 Facility-level fenceline data are from EPA, "EJScreen." Nationwide data are from U.S. Census Bureau, "ACS Demographic and Housing Estimates, 2018: ACS 5-Year Estimates Data Profiles."

100 EPA, "Health Concerns About Spray Polyurethane Foam," October 14, 2015, https://www.epa.gov/saferchoice/health-concerns-about-spray-polyurethane-foam. Guo et al., "Summary of Technical Information."

101 Anila Bello et al., "Exposure to Organophosphate Flame Retardants in Spray Polyurethane Foam Applicators: Role of Dermal Exposure," Environment International 113 (April 2018): 55–65, https://doi.org/10.1016/j.envint.2018.01.020. Cheryl Fairfield Estill et al., "Assessment of Spray Polyurethane Foam Worker Exposure to Organophosphate Flame Retardants Through Measures in Air, Hand Wipes, and Urine," Journal of Occupational and Environmental Hygiene 16, no. 7 (July 3, 2019): 477–88, https://doi.org/10.1080/15459624.2019.1609004. Michel Dedeo and Suzanne Drake, "Healthy Environments: Strategies for Avoiding Flame Retardants in the Built Environment," Perkins & Will Research, October 15, 2014, https://research.perkinswill.com/articles/healthy-environments-strategies-for-avoiding-flame-retardants-in-the-built-environment/. Dzhordzhio Naldzhiev, Dejan Mumovic, and Matija Strlic, "Polyurethane Insulation and Household Products—A Systematic Review of Their Impact on Indoor Environmental Quality," Building and Environment 169 (February 1, 2020): 106559, https://doi.org/10.1016/j.buildenv.2019.106559 . Dustin G. Poppendieck, Mengyan Gong, and Lauren E. Lawson, "Lessons Learned From Spray Polyurethane Foam Emission Testing Using Micro-Chambers," presentation at the 59th Annual Polyurethanes Technical Conference, Baltimore, 2016, http://ws680.nist.gov/publication/get_pdf.cfm?pub_id=921259.

102 Energy Efficiency for All, "A Guide to Healthier Upgrade Materials."

103 Huntsman Building Solutions, "Environmental Product Declaration: Heatlok." SPFA, "Environmental Product Declaration: Spray Polyurethane Foam Insulation (HFC)."

104 EPA, "Flame Retardant Alternatives for Hexabromocyclododecane (HBCD)," June 2014, https://www.epa.gov/sites/production/files/2014-06/documents/hbcd_report.pdf.

105 Spray Foam Coalition, "Guidance on Best Practices for the Installation of Spray Polyurethane Foam," 2012, https://polyurethane.americanchemistry.com/Spray-Foam-Coalition/Guidance-on-Best-Practices-for-the-Installation-of-Spray-Polyurethane-Foam.pdf. Laura Minet et al., "High Production, Low Information: We Need to Know More About Polymeric Flame Retardants," Environmental Science & Technology 55, no. 6 (February 22, 2021): 3467–69, https://doi.org/10.1021/acs.est.0c08126. Carsten Lassen et al., "Microplastics: Occurrence, Effects and Sources of Releases to the Environment in Denmark," Danish Environmental Protection Agency, 2015, https://mst.dk/service/publikationer/publikationsarkiv/2015/nov/rapport-om-mikroplast. Mark Spence and Cynthia Graham, "Evaluation of Particulates Generated During Trimming and Cutting of Spray Polyurethane Foam Insulation," presented at Polyurethanes Technical Conference, Houston, 2010, https://www.americanchemistry.com/industry-groups/center-for-the-polyurethanes-industry-cpi/resources/library/evaluation-of-particulates-generated-during-trimming-and-cutting-of-spray-polyurethane-foam-insulation.

106 Yaru Cao et al., "Intra-Day Microplastic Variations in Wastewater: A Case Study of a Sewage Treatment Plant in Hong Kong," Marine Pollution Bulletin 160 (November 1, 2020): 111535, https://doi.org/10.1016/j.marpolbul.2020.111535. GESAMP: Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection, Sources, Fate and Effects of Microplastics in the Marine Environment: A Global Assessment, 2015, https://ec.europa.eu/environment/marine/good-environmental-status/descriptor-10/pdf/GESAMP_microplastics%20full%20study.pdf.

107 Tait et al., "The Health Impacts of Waste Incineration." Domingo et al., "Adverse Health Effects."

108 World Energy Council, World Energy Resources: Waste to Energy, 2016, https://smartnet.niua.org/sites/default/files/resources/weresources_waste_to_energy_2016.pdf. Tait et al., "The Health Impacts of Waste Incineration."

109 Aaron Gouveia, " 'Green' Insulation Suspected as Cause of Fatal Fire," Cape Cod Times, May 20, 2008, https://web.archive.org/web/20130131034138/http://www.capecodonline.com:80/apps/pbcs.dll/article?AID=/20080520/NEWS/805200318/-1/rss01. Martin Holladay, "Three Massachusetts Home Fires Linked to Spray-Foam Installation," Green Building News, August 16, 2011, http://www.greenbuildingadvisor.com/blogs/dept/green-building-news/three-massachusetts-home-fires-linked-spray-foam-installation. "Spontaneous Combustion of Insulation Blamed in Stella's Fire," CBC News, October 8, 2015, http://www.cbc.ca/news/canada/manitoba/spontaneous-combustion-of-insulation-blamed-in-stella-s-fire-1.3263923. Debra Bogstie, "Homeowner Moves On After Devastating Middlebury Fire," NBC Connecticut, July 14, 2014, http://www.nbcconnecticut.com/news/local/Homeowner-Moves-On-After-Devastating-Fire-267070781.html.

110 Guo et al., "Summary of Technical Information."

111 David A. Purser, Effects of Exposure of Grenfell Occupants to Toxic Fire Products—Causes of Incapacitation and Death, Phase 1 Report: General Description of Hazards Excluding Comprehensive References to Individual Occupants, Hartford Environmental Research, November 5, 2018, https://assets.grenfelltowerinquiry.org.uk/documents/Professor%20David%20Purser%20report%20%28Phase%201%20-%20supplemental%29%20DAPR0000001.pdf.

112 Guo et al., "Summary of Technical Information." Per Blomqvist et al., "Isocyanates, Aminoisocyanates and Amines From Fires—a Screening of Common Materials Found in Buildings," Fire and Materials 27, no. 6 (2003): 275–94, https://doi.org/10.1002/fam.836. Frans Christensen et al., Survey of Certain Isocyanates (MDI and TDI), Danish Environmental Protection Agency, 2014, https://www2.mst.dk/Udgiv/publications/2014/01/978-87-93026-91-9.pdf.

113 David A. Purser, "Toxic Combustion Product Yields as a Function of Equivalence Ratio and Flame Retardants in Under-Ventilated Fires: Bench-Large-Scale Comparisons," Polymers 8, no. 9 (September 3, 2016), https://doi.org/10.3390/polym8090330. Kenneth W. Fent et al., "Airborne Contaminants During Controlled Residential Fires," Journal of Occupational and Environmental Hygiene 15, no. 5 (May 4, 2018): 399–412, https://doi.org/10.1080/15459624.2018.1445260. Kenneth W. Fent et al., "Flame Retardants, Dioxins, and Furans in Air and on Firefighters' Protective Ensembles During Controlled Residential Firefighting," Environment International 140 (July 1, 2020): 105756, https://doi.org/10.1016/j.envint.2020.105756.

114 Fent et al., "Flame Retardants, Dioxins, and Furans." Fent et al., "Airborne Contaminants During Controlled Residential Fires." Beverly Shen et al., "Organophosphate Flame Retardants in Dust Collected From United States Fire Stations," Environment International 112 (March 2018): 41–48, https://doi.org/10.1016/j.envint.2017.12.009. David Bell et al., "Flame Retardants and Firefighter Exposure and Health," Minnesota Department of Health, January 2016, https://www.health.state.mn.us/communities/environment/risk/docs/studies/retardantreport.pdf.

115 Fatemeh Nassreen Olang, "Non-isocyanate Spray Foam," United States US8604091B2, patent application filed August 30, 2011, and patent issued December 10, 2013, https://patents.google.com/patent/US8604091B2/en. SprayFoam, "Gaco Western Shatters the Spray Foam Isocyanate Ceiling at the Sprayfoam 2017 Convention & Trade Show," February 2, 2017, https://www.sprayfoam.com/foam-news/gaco-western-shatters-the-spray-foam-isocyanate-ceiling-at-the-sprayfoam-2017-convention-trade-show-/2927. EPA, "Green Chemistry Challenge: 2021 Academic Award," April 28, 2021, https://www.epa.gov/greenchemistry/green-chemistry-challenge-2021-academic-award. EPA, "Presidential Green Chemistry Challenge: 2015—Designing Greener Chemicals Award," July 6, 2015, https://www.epa.gov/greenchemistry/presidential-green-chemistry-challenge-2015-designing-greener-chemicals-award.

116 UN Environment Programme, "Social Life Cycle Assessment (S-LCA)," Life Cycle Initiative, accessed April 6, 2022, https://www.lifecycleinitiative.org/starting-life-cycle-thinking/life-cycle-approaches/social-lca/.

117 State of New Jersey Office of the Governor, "Governor Murphy Signs Historic Environmental Justice Legislation," September 18, 2020, https://www.nj.gov/governor/news/news/562020/20200918a.shtml.

118 American Chemical Society, "12 Principles of Green Chemistry," https://www.acs.org/content/acs/en/greenchemistry/principles/12-principles-of-green-chemistry.html (accessed May 4, 2021).

119 Delegates to the First National People of Color Environmental Leadership Summit, "Principles of Environmental Justice," https://www.ejnet.org/ej/principles.html (accessed November 8, 2021).

120 Facility-level fenceline data are from EPA, "EJScreen." Nationwide data are from U.S. Census Bureau, "ACS Demographic and Housing Estimates, 2018: ACS 5-Year Estimates Data Profiles." State-level data are from U.S. Census Bureau, "ACS Demographic and Housing Estimates, 2018: ACS 5-Year Estimates Detailed Tables," https://data.census.gov/cedsci/table?q=race%202018&t=Native%20Hawaiian%20and%20Pacific%20Islander%3ARace%20and%20Ethnicity&g=0100000US%240400000&d=ACS%205-Year%20Estimates%20Detailed%20Tables&tid=ACSDT5Y2018.B03002&hidePreview=true (accessed September 16, 2021).

energyefficiencyforall.org

ENERGY
EFFICIENCY
FOR ALL

energyefficiencyforall.org